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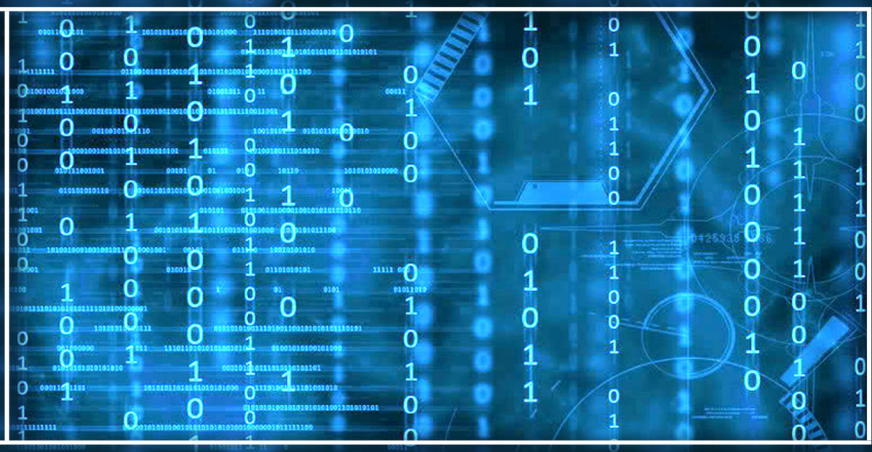

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Editorial Preface

From the Desk of Managing Editor…

It may be difficult to imagine that almost half a century ago we used computers far less sophisticated than current home desktop computers to put a man on the moon. In that 50 year span, the field of computer science has exploded.

Computer science has opened new avenues for thought and experimentation. What began as a way to simplify the calculation process has given birth to technology once only imagined by the human mind. The ability to communicate and share ideas even though collaborators are half a world away and exploration of not just the stars above but the internal workings of the human genome are some of the ways that this field has moved at an exponential pace.

At the International Journal of Advanced Computer Science and Applications it is our mission to provide an outlet for quality research. We want to promote universal access and opportunities for the international scientific community to share and disseminate scientific and technical information.

We believe in spreading knowledge of computer science and its applications to all classes of audiences. That is why we deliver up-to-date, authoritative coverage and offer open access of all our articles. Our archives have served as a place to provoke philosophical, theoretical, and empirical ideas from some of the finest minds in the field.

We utilize the talents and experience of editor and reviewers working at Universities and Institutions from around the world. We would like to express our gratitude to all authors, whose research results have been published in our journal, as well as our referees for their in-depth evaluations. Our high standards are maintained through a double blind review process.

We hope that this edition of IJACSA inspires and entices you to submit your own contributions in upcoming issues. Thank you for sharing wisdom.

Thank you for Sharing Wisdom!

Managing Editor
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Editorial Board

CONTENTS

Hybrid Geo-Location Routing Protocol for Indoor and Outdoor Positioning Applications

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***Abstract*—Internet of Things (IoT) essentially demands smart connectivity and contextual awareness of current networks with low power and cost effective wireless solutions. Routing is the backbone of the system controlling the flow of transmission. This work demonstrates a collation between performance investigations of a location-based routing protocol Geocast Adaptive Mesh Environment for Routing with contextual information collected from Global Positioning System (GPS) and Framework for Internal Navigation and Discovery (FIND) respectively. The systems are evaluated based on various metrics i.e. Accuracy, Packet Delivery Ratio and Packet Overhead by means of Network Simulator (NS-2). FIND shows enhanced performance in most cases as compared to GPS for indoor and outdoor environments. The results of this research can be deployed in different areas such as in-building navigation, hospital patient tracking, Smart City context aware service provisioning and Industry 4.0 deployments.**

Keywords*—Internet of Things (IoT); Network Simulator (NS-2); Routing; Geocast Adaptive Mesh Environment for Routing (GAMER); Mobility; Global Positioning System (GPS); Framework for Internal Navigation and Discovery (FIND)

I. Introduction

Historically, the wireless networks started during the 1970s and their significance has been growing subsequently since. An Ad hoc Network is a temporary network without any wires, specific infrastructure and administrative intervention. A MANET consist of wireless mobile nodes that formulates a system short of communication frame or standard support services. MANETs are considered as the next generation of networks. Two hosts in a MANET may route their traffic using hops through other hosts in the network [1]. Unpredictable topology variation can be caused due to host mobility. Therefore, discovering and sustaining routes in a MANET is substantial [2].

IoT is briskly accelerating into the technological world by linking the everyday objects to Internet. The significance of an emerging area like IoT in technical, economic and social fields is exceptional. This concept is still considered largely theoretical on one hand but also a network that is used every single day on the other. The effect of IoT in our everyday life primarily incorporates transportation, health and exercise, home (smart home), business, pollution and waste management, etc. [3]. Intelligent and self-configuring nodes (things) interconnected in an influential and global network framework defines the IoT prototype. It serves as one of the most disruptive technologies, presenting practical scenarios for ubiquitous and pervasive computing. Real world and small things with substantial concerns with respect to performance, privacy, security and reliability along with limited processing and storage capacity generally defines IoT [4]. This revolutionary idea gives indication to the possibility of smart cities, campuses, health care systems etc.

An Ad-Hoc wireless network comprises of a group of dynamically and randomly dispersed mobile nodes that are independent of permanent structure as opposed to IoT. Nevertheless, excessive similarities among node movements have been observed between IoT and Ad-Hoc networks [5]. For effective transmission between nodes, a range of existing Ad-Hoc routing protocols have been researched and subjugated.

Geocast Routing takes advantage of the contextual information for routing. Routing of information (from source to destination) is the significant part of any IoT and wireless sensor network (WSN) solutions. Multi-hop transmissions are the basis of node topology and has been utilized in healthcare, environment monitoring and many other smart systems [6]. By utilizing location information for mobile hosts, overhead of route discovery can be minimized. This location data is typically assimilated through GPS. However, the cost, size and power requirement of the sensor devices surges due to the addition of GPS devices. GPS is not suitable for indoor applications and results in additional power intake [7].

For acquiring efficient routing numerous routing protocols have been envisioned. When hosts move, these protocols vary in the technique adopted for finding a new route and/or modifying an existing one. However, one of the grass root problems in mobile computing is localization of a device [8]. The design and implementation of location aware systems became conceivable due to the importance and need of location information. Failure of Global Positioning System (GPS) in indoor and urban environments played a fundamental role in the development of indoor location dependent systems.

Geocoding is the process of converting human-readable addresses into machine-process able geographic co-ordinates (i.e. longitude and latitude). When working with data usually there are human-readable location names (e.g. London) but for a computer to process the location geographical coordinates (e.g. longitude = 51.745, latitude= -0.81) are needed provided

by geocoding process. Geocoding needs a database containing listed names of places and their corresponding geographical coordinates. Various open source databases such as geo-names and Open Street Map are available on the internet.

FIND is a simplified way to achieve indoor positioning. It lets us gather indoor location information by our computer (Wi-Fi enabled) or smartphones. Location can easily be discovered inside the homes (bedroom, kitchen, living room etc.) or offices [9]. It was designed with an aspiration to replace motion sensors. Therefore, because of its high resolution, it can replace any motion sensors deployed. It can supply explicit location and user-particular information. FIND can be used as an information source for operations performed through the data collected by motion sensors and GPS. However, apart from this, it provides indoor positioning making the overall system more accurate than the systems mentioned. The geolocation accuracy of FIND is below 10 sq. ft., which puts it way ahead of GPS. FIND backs information reception from any source and has integral passive scanning operation [10]. The geocast data acquired through FIND may be used from minimal lifestyle tracking and household automation to extensive commercial applications.

The remaining paper is formulated as below. Section 2 clarifies Geocast Protocols and their categories. Section 3 enlightens the Geocoding and its available sources. Section 3 also administers an outline of routing protocol used in the study. Section 4 and 5 describe the simulation environment and performance parameters while Section 6 contains the results obtained from simulation trials. Finally, conclusion of the paper is enclosed in Section 7.

II. GEOCAST PROTOCOLS

Geocast Routing makes use of the contextual information i.e. Location of sensor nodes. For nodes in close proximity, location information is dispatched through signal strength. While for distant nodes, location information can be addressed through information exchanged between neighboring nodes. One of the leading limitations for efficient data transmission is power consumption. Sleep mode of nodes tends to decrease the power consumption [11]. Contrary to other protocols (where the data packet is transmitted to a target node within a network), the destination will be a geographic region provided by geocast group.

These protocols include Flooding [12], Voronoi (Voronoi diagram based geo-casting protocol) [12], LBM (Location-Based Multicast) [13], GAMER (Geocast Adaptive Mesh Environment for Routing) [14]. Geo-GRID [15], URAD (Unicast Routing with Area Delivery) [16] and TORA (Temporally Ordered Routing Algorithm) [17]. The main comparative characteristics between geocast protocols are enlisted in Table I.

A flooding-based LBM, routing based GAMER and cluster based Geo-GRID protocols have been studied and compared in [18] based on node mobility, node speed and node density. Although Geo-GRID has a substantial performance in compact environment as compared to GAMER and LBM, GAMER triumphs in packet overhead with the lowest value.

TABLE. I. COMPARISON OF GEOCAST ROUTING PROTOCOLS

Protocol	Type of Routing	Scalability	Memory Requirement
Flooding [12]	Flooding	Low	No
Voronoi [12]	Flooding	Medium	Low
LBM [13]	Flooding	Medium	Low
GAMER [14]	Routing	Medium High	Medium
Geo-GRID [15]	Flooding	Low High	Low
URAD [16]	Routing	Medium High	Low
TORA [17]	Routing	High	Medium

Reference [19] discusses the performance of GAMER, Geo-GRID and Geo-TORA. The study is based on the selection of geocast area and efficient routing of these protocols. GAMER and Geo-GRID follow a mesh of routes between source and destination in a geocast area. However, Geo-TORA follows unicasting followed by flooding in the geocast region for routing.

III. GAMER OVERVIEW

A guide-based protocol GAMER is selected for the comparative study and was developed by the researchers as mentioned in [20]. This is a position centered routing protocol for ad hoc networks. A fusion of flooding and greedy protocols makes up this approach. A web of routes is sustained between the transmitting node and destination region in a highly scalable routing protocol. The excessive paths present in the mesh are available in case of link failure occurring due to dynamic topology in ad hoc networks. The suitable path for packet forwarding is determined via link interval of the feedback at each node. This ensures the delivery of data packets in this approach. Conversely, an idleness of relay nodes in the forwarding area and an extensive endwise delay is fashioned. Furthermore, if a forwarding node does not have adjacent nodes in the route of targeted node the dispatch of data packets in that way remains incomplete [21].

Inside a forwarding zone, JOIN-DEMAND (JD) packets are flooded to establish the mesh. A JT packet is produced and unicasted back to the transmitting node by receiving node inside geocast region after the reception of a non-replicate JD packet. The path taken by JT packet is the same followed by JD packet previously. The mesh makes each node used for reverse routing its member. The mesh members circulate the geocast packets produced by source node within mesh and flood them inside the target area.

GAMER prefers FA (Forwarding Approach) to minimize the load as much as it can and changes the complexity of the mesh effectively. GAMER operates on adaptation and changes it forwarding area to a smaller size if the existing one thrives and to a larger size if it declines. There are three types of FAs a node in GAMER can pick from i.e. CONE CORRIDOR and FLOOD. First type of FA is called FLOOD, which floods the JD packets all through the network (ad hoc). A forwarding area is established in order to minimize the flooding area for Join Demand packets in the remaining two types of FA. Mobile Networks (MN) inside the forwarding zone are capable of

flooding the JD packets exclusively. In CORRIDOR approach, a rectangle shaped forwarding zone is produced by considering the region between two parallel lines curved around the geocast region. In CONE FA, forwarding zone in a mesh is the area confined by an angle. Source node is at the vertex of this angle while geocast region is the area present between its sides. In comparison, the forwarding zone in FLOOD forwarding area is much bigger than forwarding area in CORRIDOR FA [14]. The mesh created by CONE FA has even more confined forwarding zone relative to mesh created by CORRIDOR FA.

The transitional nodes do not need to be aware of or forward the routing state of other neighboring nodes in GAMER, which is considered as its main interest. On the other hand, importing the complete route from source to the target by data packets results in increased overhead, adding to the drawbacks.

IV. Simulation Environment

The network simulator NS-2 [22] is used to implement geocast protocol, distinctly prominent in ad hoc network community. The simulation region is rectangle shaped with 300 x 600 m dimensions. The Geocast region is in the form of 150 x 150 m square positioned at the upper right corner. A stationary node is placed at the center of Geocast region to guarantee the presence of one node for reception of transmitted geocast packets. Transmission Range for each Mobile Node (MN) is uniform i.e. 100 meters each mobile node has the link bandwidth of 2 Mbps. A 64-byte geocast data packet is generated by a single CBR (Constant Bit Rate) source for every 1000-second simulation period. To bypass unneeded collisions, a uniform random jitter is introduced in packet scheduling.

Random waypoint mobility model is used for movement of nodes [23]. In this model, each node grows from a random starting point to a randomly picked target. The node takes a rest period at the target and picks another random destination after the pause time. This cycle is replicated throughout the simulation period resulting in regular topology changes of the network. [24] Suggests that for a random waypoint model, location initialization and Mobile Node pause time is established with the steady state distribution to escape the initialization difficulty of the model.

TABLE. II. Simulation Parameters [25]

Parameter	**Value**
Simulator	NS-2
Protocol	GAMER
Simulation Area	300 x 600 m^2
Simulation Time	200 sec
Geocast Region	150 x 150 m^2
Transmission Range	100 m
Data Payload	Bytes/packet
Link Capacity	2 Mbps
Traffic	Constant Bit Rate
Node Movement Model	Random waypoint

The summary of model parameters adopted in the simulation trials are specified in Table II.

It is necessary for the data packets to either find a geocast region or expire during the trials. Partition less initialization and timely execution of simulation trials is achieved for this purpose. During simulation trials, data packets are sent with 1 second delay to allow time for formation of mesh and grid. Several simulation trials are performed to present average results.

V. Evaluation Parameters

A. Accuracy

Accuracy of a system is the indication of proximity of a calculated quantity to a standard quantity. An error ratio between the measured values to the possible range of values is also accounted as accuracy. For location aware systems, the accuracy is determined in terms of distance. It is the difference between the position found by the system and the actual position.

B. Packet Overhead

Packet Overhead is the amount of time taken for a transmission over a packet – switched network. It is a type of information added to packet header to assure packet delivery to the destination. At the time of network simulation, the overhead is essentially the additional bytes transmitted.

During entire simulation interval i.e. transmission from source to destination nodes, all the packets transmitted are numbered. These labels are usually known as packet overhead. These include any supplementary transmissions taking place for routing data packets i.e. acknowledgements, hello message, control messages etc.

It is considered as the wasted bandwidth as it decreases the comprehensive transmission speed of a data packet.

C. Packet Delivery Ratio

PDR is a ratio among the amount of message packets directed by the source and the amount of message packets acknowledged by the target.

The efficiency of the system is directly proportional to the PDR value of that system. The higher the PDR value, the higher the efficiency of the system. PDR of a system can be calculated by a simple formula as below:

$$PDR=Pr/Pt \quad (1)$$

In above equation Pr represents the data packets received by the target node while Pt shows the data packets sent by the source node.

VI. Results and Discussions

For this simulation, mesh created through CONE has been chosen. The mesh created by CONE FA has a narrow forwarding zone relative to mesh created by other techniques. Results for GPS based system have been obtained from [20] and are then compared to the results for FIND based system. The original node positions, their accuracy and forwarding area is presented in Fig. 1.

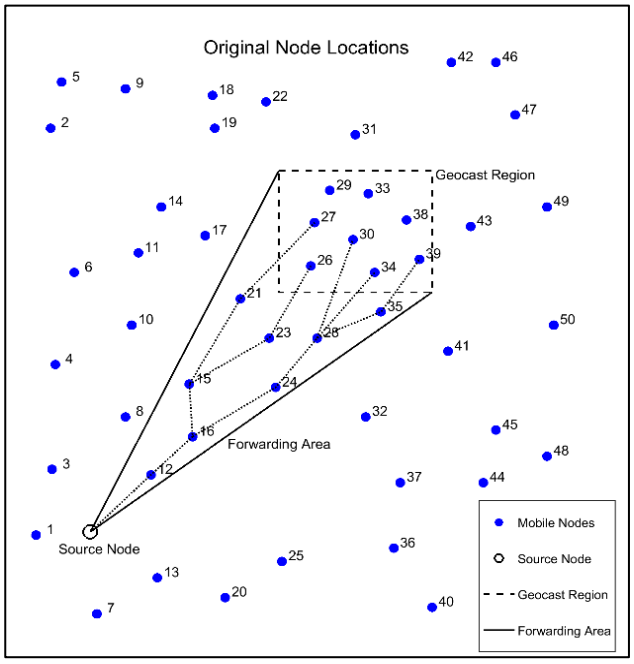

Fig. 1. Forwarding Area for Original Node Locations

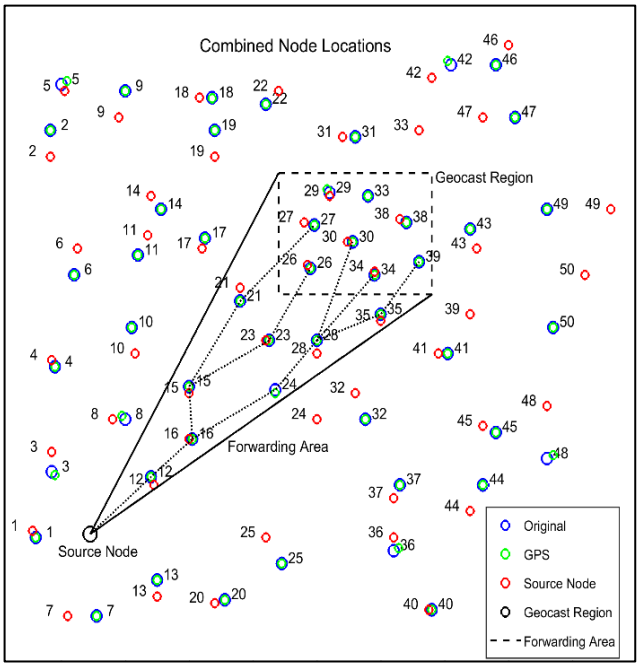

Fig. 2. Combined Node Locations (FIND and GPS).

A. Accuracy

The accuracy is one of the most important parameters for a location-based system. It is clearly seen from Fig. 2 the node positions provided by two different information systems i.e. FIND and GPS are different. Fig. 2 displays most of the node positions accurately found through FIND. This is due to the high geolocation accuracy of FIND i.e. 10 sq. feet. The forwarding area selected by using FIND contains accurate node positions, which makes the transmission and delivery of a data packet straightforward.

Fig. 2 also presents the node locations provided through GPS. It is clear that not all the node positions are accurate. This is the result of low GPS accuracy i.e. 3 – 5 m. The forwarding area selected by using GPS contains some of the inaccurate nodes. This results in low and complicated packet transmission and delivery.

Fig. 3 and 4 show the variation of node locations reported by FIND and GPS systems in comparison to original node locations for indoor and outdoor environments respectively. The x-axis shows each node numbers while y-axis shows the distance error from original positions. The original nodes in blue are taken as a reference and considered at origin i.e. zero axis position. The dashed lines show the error margin of these nodes. The nodes in green are FIND based nodes while nodes in red are GPS based nodes.

It is quite clear from the graphs that GPS operates better in outdoor environments providing greater precision due to the larger distance between nodes. As for indoor environments, GPS shows higher inaccuracy due to the smaller distance between nodes. This behavior results in an inefficient system.

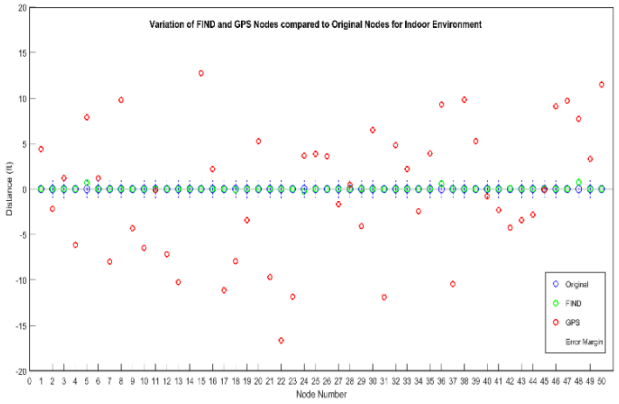

Fig. 3. Variation of FIND and GPS Nodes Compared to Original Nodes for Indoor Environment.

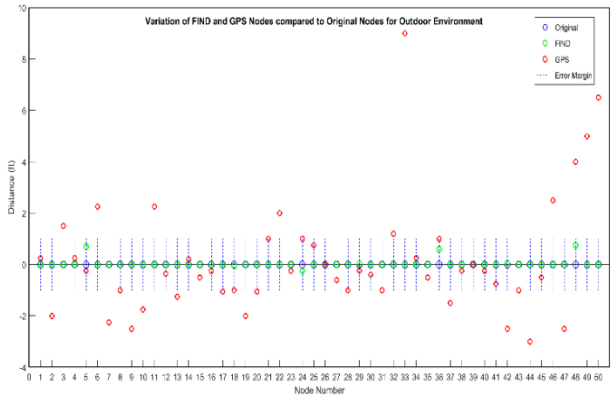

Fig. 4. Variation of FIND and GPS Nodes Compared to Original Nodes for Outdoor Environment.

B. Packet Overhead Vs Number of Nodes

Fig. 5 demonstrates Packet Overhead per one success with respect to Number of Nodes for both systems. For simplicity the first analysis is accomplished with static nodes and Null MAC. The number of nodes are increased step by step from 30 to 120. The source packet rate is kept constant at 40 packets per sec. But due to Null MAC the packet source rate has no effect on the Packet Overhead of the system. The delivery of packets in this case is almost 100 percent.

The result shows that GAMER is very economical in case of Packet Overhead. With the increase in number of nodes Packet Overhead for both cases increases. However, the Packet Overhead per One Success of GAMER is much lower with contextual information obtained through FIND in comparison to information acquired through GPS. This is due to the fact that location information delivered by GPS is in the form of latitude and longitude. The data packet is at least 24 bytes long which results in enlarged Packet Overhead for the system operating on GPS. However, location information delivered by FIND is geocoded and can easily be sent in maximum 8 bytes decreasing the Packet Overhead of the system. Therefore, the system based on FIND shows better performance and is less prone to error than GPS based system.

A clear increase in Packet Overhead for both systems is observed when then number of nodes crosses 80. The reason for this increase is the increase in grid density i.e. Grids have more than one nodes when the number of nodes exceeds 80.

C. Packet Delivery Ratio Vs Source Packet Rate

Fig. 6 shows the graph between Packet Delivery Ratio and Source Packet Rate. In this study the PDR is calculated while varying Source Packet Rate from 1–80 packets/sec. The number of nodes is set at 80. The network is kept static with 802.11 MAC. One parameter is varied to efficiently observe the behavior of the system. The system is kept static to exclude the effect of mobility. It is carried out to observe the effect of congestion over a network.

PDR has an inverse relationship with source packet rate. The PDR is almost 100% for source packet rate up to 30 pkts/sec. Nevertheless, both the systems start showing a decrease in the PDR with further increase in source packet rate. However, the behavior of the FIND based system is much better than the GPS based system according to Fig. 6.

D. Packet Overhead Vs Source Packet Rate

Packet Overhead for a static network with 802.11 MAC is shown in Fig. 7. The system parameters are kept the same as in previous analysis. GAMER has a periodic control overhead which results in no significant change in Packet Overhead with increasing Source Packet Rate. However, it does have a downside i.e. really high packet overhead for low packet rates. For both FIND and GPS based systems GAMER follows the same behavior i.e. Packet Overhead is extremely high for low packet rates, stays the same for medium rates and increases when the network becomes crowded. However, considering the larger size of a GPS Packet and performance of both the systems FIND has a superior performance than a GPS based system.

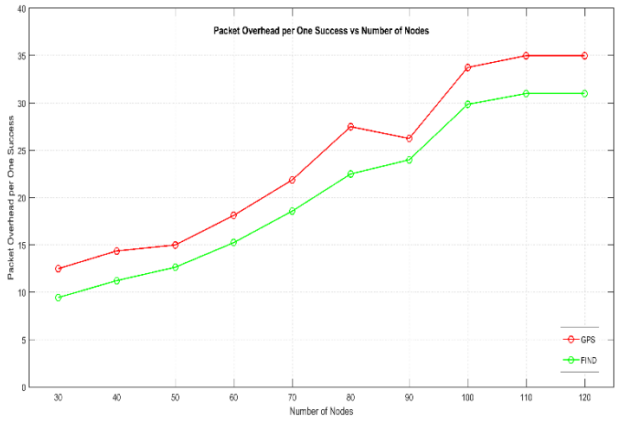

Fig. 5. Packet Overhead vs Number of Node.

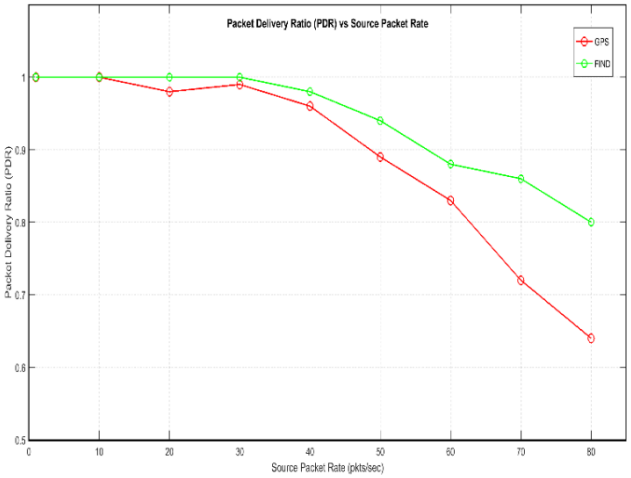

Fig. 6. PDR vs Source Packet Rate.

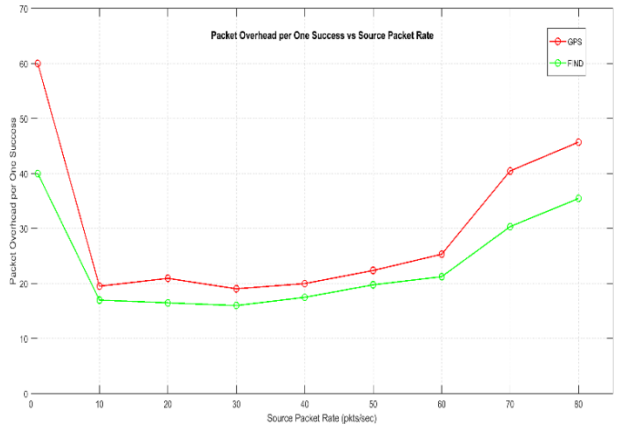

Fig. 7. Packet Overhead vs Source Packet Rate

E. Packet Delivery Ratio Vs Average Node Speed

The next result is based on mobile nodes to observe the effect of mobility on the systems. The system parameters such as source packet rate and number of nodes are set at 40pkts/sec and 80, respectively. To avoid the effects of traffic Null MAC is used same as first case. PDR is noticed with differing average node speed from 1–20 m/s.

The performance of both the systems remains well i.e. greater than 97% in most cases. GAMER has the tendency to drop the performance with increasing speed. This fact is seen prominently in Fig. 8. However, the performance decline in FIND based system is far less than GPS based system. The delivery ratio in FIND based system is higher due to better accuracy of the nodes contained in the forwarding area.

F. Packet Overhead vs Average Node Speed

Packet Overhead vs Average Node Speed is presented in Fig. 9. The system parameters are the same as the previous section. It was already discussed in section *B* that GAMER has a low packet overhead for higher number of nodes. Therefore, even for mobile networks the packet overhead for single success is low as well.

The need to maintain a mesh for transmission is often the reason for increase in packet overhead. The movement of mobile nodes makes it difficult to maintain a mesh throughout the transmission resulting in increased overhead. Although due to inaccuracy of GPS, the incorrect node positions puts the packet overhead level even higher for GPS based GAMER in comparison to FIND based GAMER system.

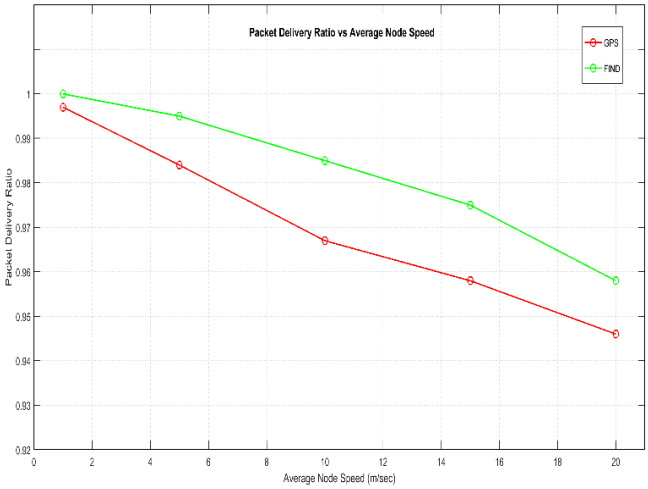

Fig. 8. PDR vs Node Speed.

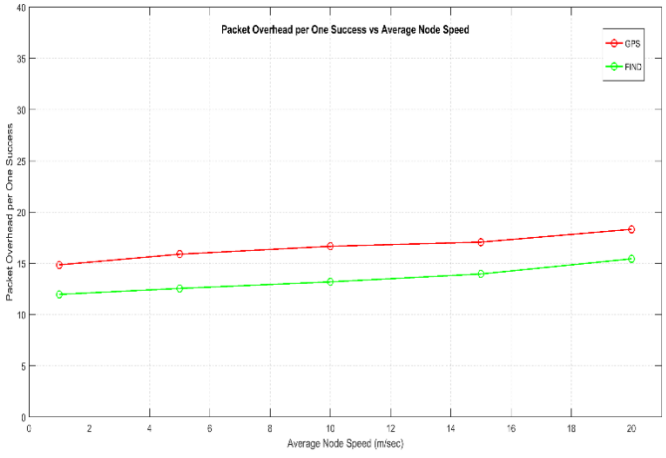

Fig. 9. Packet Overhead vs Node Speed.

VII. Conclusion and Future Work

The stated research analyzed a location-based routing protocol GAMER for ad hoc networks based on the two different geolocation systems i.e. GPS and FIND. The performance analysis was centered on Accuracy, Packet Delivery Ratio (PDR) and Packet Overhead of the system. The evaluation discloses that FIND based GAMER performs better in most cases. Results obtained are better than GPS in both indoor and outdoor environment (with mobility). Accuracy of FIND is below 10 sq. ft. as compared to GPS which has an accuracy up to a few meters. To study effects of congestion static nodes are considered. PDR and Packet Overhead of FIND based GAMER shows remarkable results against source packet rate (pkts/sec). Another study carried out considers mobility in a network. The performance of both systems declines as compared to static node systems. PDR of FIND based GAMER remains above 90% for most cases. However, GPS based GAMER loses the performance when the node speed surpasses 10 m/sec. A third analysis was conducted by introducing congestion as well as mobility into the network. The performance of FIND system remains superior to GPS systems in all aspects.

In case of FIND system, signals from three or more sources are required for accurate results by FIND fingerprinting. For this purpose, the concept of BYOD (bring your own device) may be used. The information provided by the personal devices can be used rather than carrying around an extra beacon. The battery consumption is almost none due to the use of pre-defined operations. Additionally, easy installation and configuration of FIND compared to other platforms makes it an ideal replacement. Taking this analysis into account, FIND based GAMER can easily replace any indoor positioning system in use.

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Phishing Websites Detection using Machine Learning

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***Abstract*—Tremendous resources are spent by organizations guarding against and recovering from cybersecurity attacks by online hackers who gain access to sensitive and valuable user data. Many cyber infiltrations are accomplished through phishing attacks where users are tricked into interacting with web pages that appear to be legitimate. In order to successfully fool a human user, these pages are designed to look like legitimate ones. Since humans are so susceptible to being tricked, automated methods of differentiating between phishing websites and their authentic counterparts are needed as an extra line of defense. The aim of this research is to develop these methods of defense utilizing various approaches to categorize websites. Specifically, we have developed a system that uses machine learning techniques to classify websites based on their URL. We used four classifiers: the decision tree, Naïve Bayesian classifier, support vector machine (SVM), and neural network. The classifiers were tested with a data set containing 1,353 real world URLs where each could be categorized as a legitimate site, suspicious site, or phishing site. The results of the experiments show that the classifiers were successful in distinguishing real websites from fake ones over 90% of the time.**

Keywords*—Phishing websites; classification; features; machine learning

I. Introduction

While cybersecurity attacks continue to escalate in both scale and sophistication, social engineering approaches are still some of the simplest and most effective ways to gain access to sensitive or confidential information. The United States Computer Emergency Readiness Team (US-CERT) defines phishing as a form of social engineering that uses e-mails or malicious websites to solicit personal information from an individual or company by posing as a trustworthy organization or entity [1]. While organizations should educate employees about how to recognize phishing e-mails or links to help protect against the above types of attacks, software such as HTTrack is readily available for users to duplicate entire websites for their own purposes. As a result, even trained users can still be tricked into revealing private or sensitive information by interacting with a malicious website that they believe to be legitimate.

The above problem implies that computer-based solutions for guarding against phishing attacks are needed along with user education. Such a solution would enable a computer to have the ability to identify malicious websites in order to prevent users from interacting with them. One general approach to recognizing illegitimate phishing websites relies on their Uniform Resource Locators (URLs). A URL is a global address of a document in the World Wide Web, and it serves as the primary means to locate a document on the Internet. Even in cases where the content of websites are duplicated, the URLs could still be used to distinguish real sites from imposters.

One solution approach is to use a blacklist of malicious URLs developed by anti-virus groups. The problem with this approach is that the blacklist cannot be exhaustive because new malicious URLs keep cropping up continuously. Thus, approaches are needed that can automatically classify a new, previously unseen URL as either a phishing site or a legitimate one. Such solutions are typically machine-learning based approaches where a system can categorize new phishing sites through a model developed using training sets of known attacks.

One of the main problems with developing machine-learning based approaches for this problem is that very few training data sets containing phishing URLs are available in the public domain. As a result, studies are needed that evaluate the effectiveness of machine-learning approaches based on the data sets that do exist. This work aims to contribute to this need. Specifically, the goal of this research is to compare the performance of the commonly used machine learning algorithms on the same phishing data set. In this work, we use a data set, where features from the data URLs have already been extracted, and the class labels are available. We have tested common machine learning algorithms for the purpose of classifying URLs such as SVM, Naïve Bayes' classifier, decision tree, and neural network.

The remainder of this paper is structured as follows. Section II describes the related work in classifying phishing URLs. Section III provides the details of the data set and methodology, Section IV describes the results of the tests and provides discussion. Section V describes limitations of the present work and directions for the future work.

II. Related Work

Machine learning techniques that identify phishing URLs typically evaluate a URL based on some feature or set of features extracted from it. There are two general types of features that can be extracted from URLs, namely host-based features and lexical features. Host based features describe characteristics of the website, such as where it is located, who manages it, and when was the site installed. Alternatively, lexical features describe textual properties of the URL. Since URLs are simply text strings that can be divided into subparts including the protocol, hostname, and path, a system can assess a site's legitimacy based on any combination of those components.

Many machine learning techniques have been used for detection of malicious URLs. Sadeh et al. [2] proposed a system called PILFER for classifying phishing URLs. They extracted a set of ten features that are specifically designed to highlight deceptive methods used to fool users. The data set consists of approximately 860 phishing e-mails and 6950 non-phishing emails. They used a Support Vector Machine (SVM) as a classifier in the implementation. They trained and tested the classifier using 10-fold cross validation and obtained 92 percent accuracy.

Ma et al. [3] considered the URL classification problem as a binary classification problem and built a URL classification system that processes a live feed of labeled URLs. It also collects URL features in real time from a large Web mail provider. They used both lexical and host-based features. from the gathered features and labels, they were able to train an online classifier using a Confidence Weighted (CW) algorithm. Parkait et al. [4] provide a comprehensive literature review after analyzing 358 research papers in the area of phishing counter measures and their effectiveness. They classified anti-phishing approaches into eight groups and highlighted advanced anti-phishing methods.

Abdelhamid et al. [5] built a system for detecting phishing URLs called Multi-label Classifier based on Associative Classification (MCAC). They used sixteen features and classified URLs into three classes: phishing, legitimate, and suspicious. The MCAC is a rule-based algorithm where multiple label rules are extracted from the phishing data set. Patil and Patil [6] provided a brief overview of various forms of web-page attacks in their survey on malicious webpages detection techniques.

Hadi et al. [7] used the Fast-Associative Classification Algorithm (FACA) for classifying phishing URLs. FACA works by discovering all frequent rule item sets and building a model for classification. They investigated a data set consisting of 11,055 websites with two classes, legitimate and phishing. The data set contained thirty features. They used the minimum support and the minimum confidence threshold values as two percent and fifty percent, respectively.

Nepali and Wang [8] proposed a novel approach to detect malicious URLs using only visible features from social networks. Kuyama et al [9] proposed a method for identifying the Command and Control server (C&C server) by using supervised learning and features points obtained from WHOIS and DNS information. They evaluated domain names and e-mail addresses from the WHOIS as input values for machine learning.

In addition to the above solutions, several researchers have surveyed the field of malicious URL detection. Sahoo et al. [10] provide a comprehensive survey and structural understanding of malicious URL detection techniques using machine learning.

III. Methodology

A. Dataset

The data set used in this paper was downloaded from the University of California, Irvine Machine Learning Repository, Center for Machine Learning and Intelligent Systems [11]. It contains features from 1353 URLs. Out of these, 548 are legitimate, 702 are phishing, and 103 are suspicious. The data set also contains nine features that were extracted from each URL. The attributes provide information such as the URL anchor, popup window, age of the domain, URL length, IP address, web traffic, etc. Each feature value holds categorical values, either binary or ternary. Binary values indicate that the existence or the lack of existence of the feature within the URL determines the value assigned to that feature. For ternary features, the existence of the feature in a specific ratio determines the value assigned to that feature. The features that we used in this research work are described in the following paragraphs.

1) Server Form Handler (SFH): Usually information is processed in the same domain where the webpage is loaded. In phishing websites, the server form handler is either empty or is transformed to another domain that is not legitimate.

2) Secure Socket Layer (SSL) final state: Phishing websites may use HTTPs protocol. This is a warning to end users letting them know that the site is not secured by SSL.

3) Popup windows: Usually, legitimate sites do not ask users their credentials via popup windows.

4) Request URL: Often, in legitimate websites, objects are loaded from the same domain where the webpage is loaded.

5) URL of the anchor: The hypertext reference is used to specify a target for the anchor element. If the anchor points to a different domain rather than the domain where the webpage is loaded, then the website is suspicious or phishing.

6) Web traffic: High web traffic indicates that website is used regularly and is likely to be legitimate.

7) URL length: Phishing websites often use long URLs so that they can hide the suspicious part of the URL.

8) Age of the domain: Domains that are in service for a longer period of time are likely to be legitimate.

9) Having IP address in the URL: The usage of an IP address in the domain name is an indicator of a non-legitimate website.

10)Class: In this data set, the URLs are categorized into three classes: phishing, suspicious, and legitimate.

B. Classifiers

This work used the above data set to compare the performance of four classifiers. Specifically, we used the decision tree, Naïve Bayes' classifier, SVM, and the Neural Network to classify the URLs in the data set, and then we compared the results using confusion matrices.

1) Decision tree: Decision trees are non-parametric classifiers. As its name indicates, a decision tree is a tree structure, where each non-terminal node denotes a test on an attribute, each branch represents an outcome of the test, and the leaf nodes denote classes. The basic algorithm for decision tree induction is a greedy algorithm that constructs the decision tree in top-down recursive divide-and-conquer manner [12]. At each non-terminal node, one of attributes is chosen for the split. The attribute that gives the maximum information gain is

chosen for the split. A well-known algorithm for decision trees is the C4.5 algorithm where entropy is used as a criterion to calculate the information gain. The information gain is defined as the difference between the entropy before the split and the entropy after the split. Equations to calculate information gain are below.

$$H(T) = -\sum_j p_j \log_2(p_j)$$
$$Hs(T) = -\sum_i p_i Hs(T_i)$$
$$Gain(s) = H(T) - Hs(T) \quad (1)$$

Where $H(T)$ is the entropy before the split, $Hs(T)$ is the entropy after the split, and p_j is probability of class j. One of the main concerns with the decision tree classifier is that it over fits the training data.

2) Naïve bayes' classifier: This classifier calculates the posterior probability for each class and assigns the sample to the class with the maximum probability [13]. The posterior probability for class *i* is given by Equation (2) and can be calculated from the training set data.

$$P(C_i/\mathbf{x}) = P(\mathbf{x}/C_i)P(C_i)$$
$$\text{where } P(\mathbf{x}/C_i) = \prod_{k=1}^{n} P(x_k/C_i) \quad (2)$$

In Equation (2), $P(\mathbf{x}/C_i)$ is a conditional probability.

3) Support vector machine: This classifier uses a nonlinear mapping to transform original training data into a higher dimension and finds hyper planes that partition data samples in the higher dimensional feature space. The separating hyper planes are defined as

$$Wx + b = 0 \quad (3)$$

where W is a weight matrix, and b is a constant. The SVM algorithms find the weight matrix such that it maximizes the distance between the hyper planes separating two classes. Tuples that fall on the hyper planes are called as support vectors [14].

4) Neural network: Neural networks are non-parametric classifiers. Neural networks provide a powerful alternative to statistical classifiers. Neural networks can learn with a training set data and make decisions. We built the neural network using MATLAB script. In particular, we implemented a three layer neural network with a back propagation algorithm [15, 16]. The three layers are the input layer, hidden layer, and the output layer. The number of units in the input layer is equal to the number of features, and the number of units in the output layer is equal to the number of classes. During the learning process, weights in the network are set to small random values. For each training sample, input values are propagated, and the output values at the last layer is compared with the target values to calculate the error. The backpropagation algorithm is a well-known algorithm. It uses a gradient descent method to find the minimum. The error is propagated backward to update the weights so that with each iteration, the Mean Squared Error (MSE) decreases. The iterations are terminated when the MSE is less than some constant e_{min} or the number iterations exceeds the maximum set value. The backpropagation learning algorithm can be described in the following steps.

Step 1: Initialize weights with small random values.

Step 2: Present an input vector and make a forward pass to compute weighted sums S_i and activations $o_i = f(S_i)$ for each unit, where $f(.)$ represents the activation function.

Step 3: Backpropagation: Starting with the output units, make a backward pass through output units and hidden layer units using Equations 3 and 4.

$$f'(S_i) = o_i(1 - o_i) \quad (3)$$

$$\delta_i = \begin{cases} (t_i - o_i) f'(S_i) & \text{for units in output layer} \\ \left(\sum_m w_{m,i}\delta_m\right) f'(S_i) & \text{otherwise} \end{cases} \quad (4)$$

In Equations (3) and (4), $w_{m,i}$ represents weights, and t_i represents target output.

Step 4. Update the weights using Equation 5 where α is a learning rate.

$$w_{i,j} \leftarrow w_{i,j} + \alpha \delta_i o_i \quad (5)$$

Repeat Steps 2 through Step 4 until the MSE is less that e_{min} for all samples in the training set.

IV. Results and Conclusions

A. Results

The data set we used from The University of California, Irvine Machine Learning Repository has nine attributes and contains 1,353 samples. The histogram for the first attribute is shown in Fig. 1. It can be seen that there are three peaks in the histogram that represents three classes. The architecture of the neural network is shown in Fig. 2. There are nine units in the input layer, one for each feature. The hidden layer consists of ten units, and the output layer has three units. The three units in the output layer represent the three classes. Thus, target vectors {1, 0, 0}, {0, 1, 0}, and {0, 0, 1} represent the three classes, which are phishing, suspicious, and legitimate, respectively.

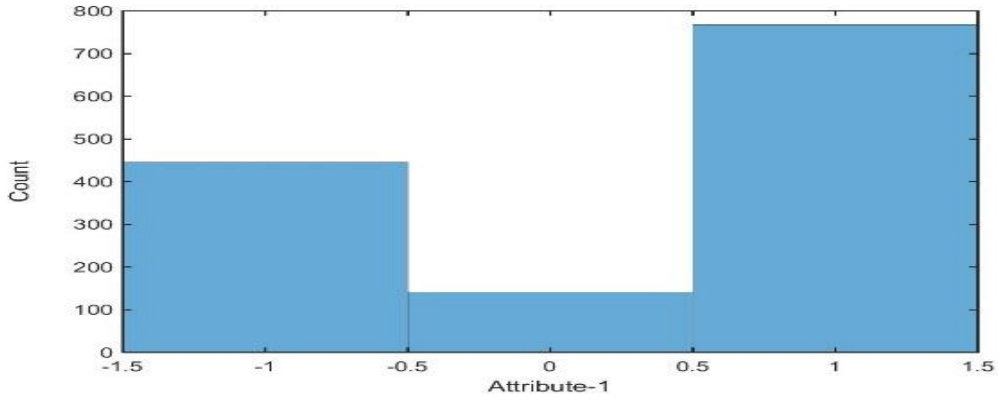

Fig. 1. Histogram for Attribute 1.

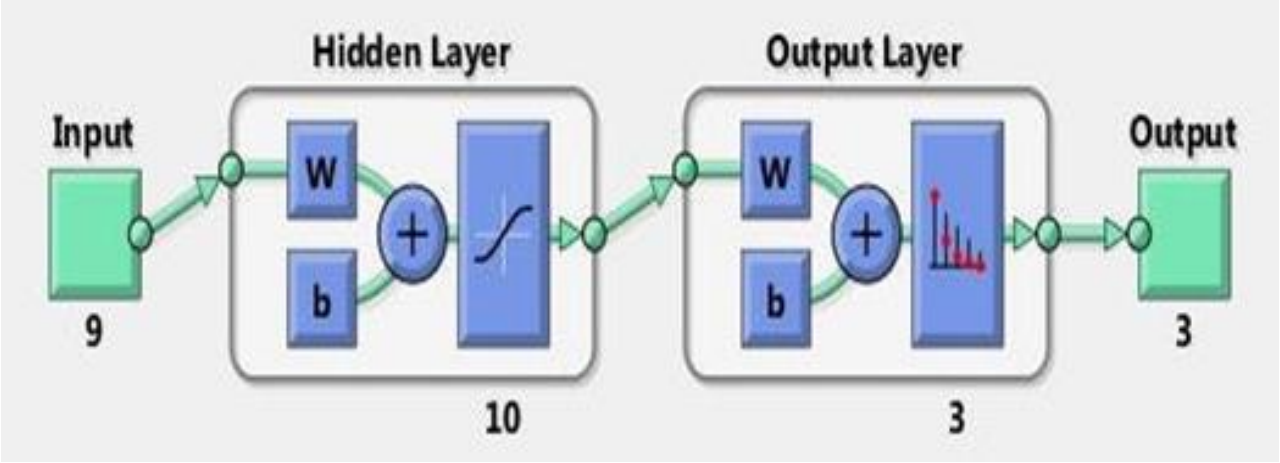

Fig. 2. A Three-Layer Neural Network.

Sixty percent of the samples were selected randomly for training the neural network. of the remaining forty percent, twenty percent were used for validation, and the other twenty percent were used for testing. The graph for the mean squared error during training states is shown in Fig. 3. for the decision tree, Naïve Bayes' classifier, and SVM, forty percent of the records were randomly selected records for training, and the remaining sixty percent were used for testing. The pruned decision tree is shown in Fig. 4. The confusion matrix obtained with the pruned decision tree class is shown in Table 1. We used the same data set as a benchmark and compared the results of all of the classifiers. The results compared included the overall accuracy, True Positive Rate (TPR), and False Positive Rate (FPR) for phishing URL samples. The results of the tests are shown in Table 2.

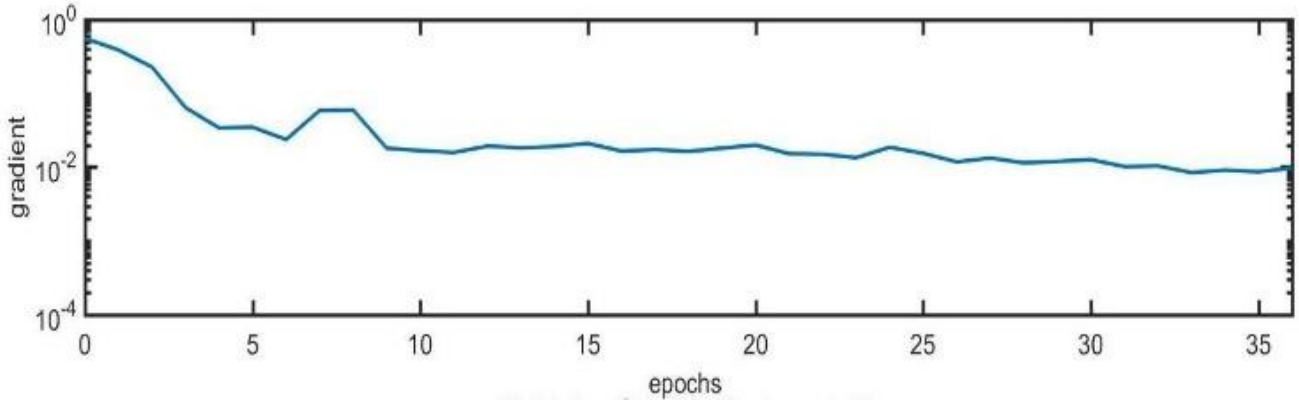

Fig. 3. Mean Squared Error.

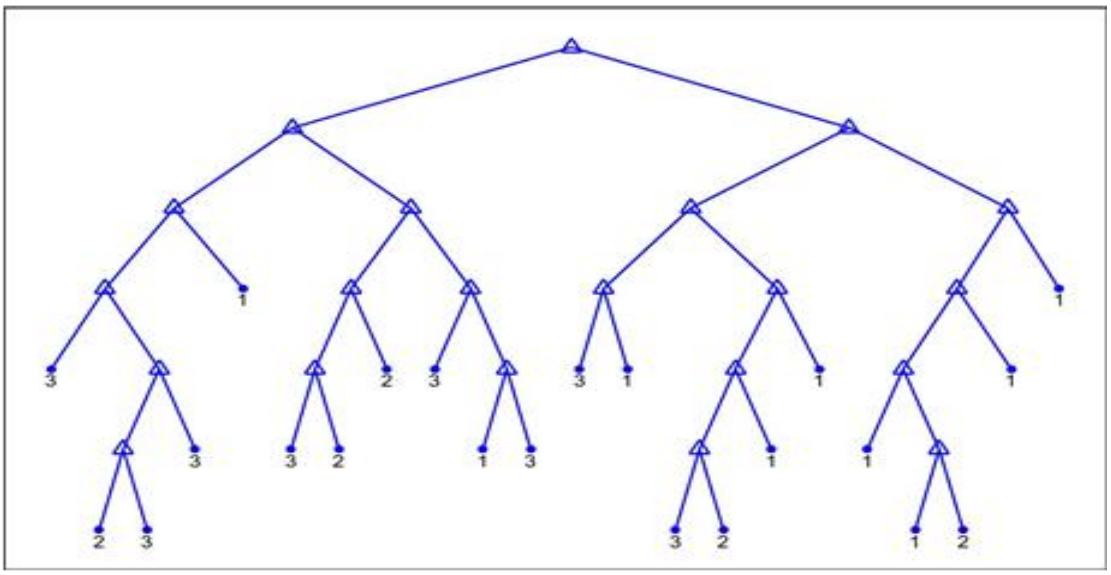

Fig. 4. A Pruned Decision Tree.

B. Conclusions

In this work, we implemented four classifiers using MATLAB scripts, which are the decision tree, Naïve Bayes' classifier, Support Vector Machine (SVM), and the Neural Network. The classifiers were used to detect phishing URLs. In detecting phishing URLs, there are two steps. The first step is to extract features from the URLs, and the second step is to classify URLs using the model that has been developed with the help of the training set data. In this work, we used the data set that provided the extracted features. The data set, from The University of California, Irvine Machine Learning Repository, contained nine features.

One of the main concerns in the decision tree classifiers is over fitting. Generally, the decision tree classifies the training set data very well but yields poor results with a testing dataset. It is often required to prune the decision tree to work well with testing data. The pruned decision tree provided the highest classification accuracy 90.39 percent. with more features in the data set it may be possible to obtain higher accuracy. In addition, the accuracy may be improved by using an ensemble of trees.

It can be seen from Table 2 that the neural network classifier yielded the lowest accuracy for this data set. One of the reasons that it did not perform well is that feature vector values were discrete which results in non-smooth decision boundaries that separate the three classes. However, it is possible to use more number of units in the hidden layer or use deep learning techniques such as adding a number of hidden layers to improve the performance of the network.

TABLE. I. CONFUSION MATRIX USING A DECISION TREE

	Phishing	Suspicious	Legitimate
Phishing	262	3	23
Suspicious	7	34	1
Legitimate	13	5	193

TABLE. II. RESULTS FOR THE TESTED CLASSIFIERS

Classifier	**TPR**	**FPR**	**Accuracy**
Pruned Decision Tree	90.97 %	7.81 %	91.5 %
SVM	90.97 %	18.18 %	86.69 %
Naïve Bayes' Classifier	88.19 %	16.21 %	86.14 %
Neural Network	85.61 %	15.91 %	84.87 %

V. FUTURE WORK

The research work presented here has some limitations and it can be extended further. The first limitation is that we considered a small data set that contains 1353 URLs, and there are 9 features for each URL. The second limitation is that all features are discrete. Often, classifiers such as decision trees, Naïve Bayes classifier, and rule-based systems are more suitable when features are discrete. Furthermore, we used features that were already extracted from URLs. The present work can be extended as below.

We can evaluate classifiers using a large data set that contains a few thousands of URLs and extract more number of features that may be significant in decision making. Larger data sets are available in public domain.

We can generate associative rules using the frequent item data sets with the minimum support and confidence values and build a rule-based system using associative rules to classify URLs. The rule-based classifier then can be compared with other classification methods. another approach for generating classification rules from data samples is to divide the feature space using fuzzy membership functions and extract and optimize classification rules [17]. The extracted rules can be used to build a fuzzy inference system that can classify URLs.

In order to avoid the problem of overfitting a classifier, we need to include a pre-process stage. In processing, we can use clustering to find out outliers or noisy data samples. Such samples should not be used in the training set data.

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Analysis of Software Deformity Prone Datasets with Use of AttributeSelectedClassifier

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***Abstract*—Software Deformity Prone datasets models are interesting research direction in the era of software world. In this research study, the interest class of software deformity prone is defective model datasets. There are different techniques to predict the deformity prone datasets model. Our proposed solution technique is AttributeSelectedClassifier with selected evaluators and searching method for reducing the dimensionality of training and testing data provided by defected models NASA datasets by attribute selection before being passed on classifiers. We have used three evaluators and search methods. These evaluators are CFSSubsetEval, GainRatio and Principal Component Analysis (PCA). The search methods are BestFirst and Ranker. We have used 12 different classifiers for analyzing the performance of these three evaluators with search methods. The experimental results and analysis are measured with True Positive (TP-Rate), Positive Accuracy, Area under Curve (ROC) and Correctly Classified Instances. The results showed that that CFSSubsetEval and GainRatio performance is better in almost classifiers. Hoeffding tree, Naive Bayes, Multiclass, IBK and Randomizable filtered class increased performance in Positive Accuracy in all techniques. Stacking has worst performance in positive accuracy and True Positive tp-rate in all over technique.**

***Keywords*—GainRatio; CFSSubsetEval; PCA; classification; defect prediction; deformity prone; defect model; classifier; bug model; softwar; attributesubsetclassifier**

I. Introduction

The presence of software deformity prone influences significantly on software unwavering quality, quality and support cost. Accomplishing without bug software likewise is diligent work, even the software connected carefully on the grounds that most time there is masked bugs. Notwithstanding, creating software deformity prone model which could foresee the flawed modules in the early stage is a genuine test in software engineering. Software deformity prone is a basic action in software advancement. This is on the grounds that anticipating the surrey modules preceding software organization accomplishes the client fulfillment, improves the general software execution. Also, foreseeing the software bug early improves software adjustment to various conditions and expands the asset use. Different methods have been proposed to handle Software deformity prone issue. The most realized methods are Machine Learning (ML) systems [1]. The Machine Learning procedures are utilized broadly in Software deformity prone to foresee the carriage modules dependent on chronicled issue information, fundamental metrics and distinctive software processing systems.

Software deformity models may show different quality as far as the quantity of faulty models. At the point when faulty models are amazingly uncommon in the dataset, this does not mean these deformity prone ought to be ignored, but instead that it is fundamental to catch them. This is known as the class imbalance issue, since there are a lot more faultless models than faulty ones. We use sampling method to address the class imbalance issue. To be specific, when the proportion of faulty models is extremely low, we use oversampling and under sampling strategies.

Many models impressing examine use NASA Repository data models. This task contains models with surely understood facts, yet in addition model quality issues. Software deformity prone created by classifiers ought to be surveyed as far as accuracy. While much experimental analysis used the area under the curve (AUC) which is also known as Receiver operating characteristic (ROC) curve, we incorporate an option, to be specific the F-measure, to address the potential impediments of the AUC. Our elective measure corrects the misusing of figuring misclassification rates in AUC. While observing the numerical differences in forecast results coming about because of the utilization of different metrics on different models, factual tests check whether these differences are measurably significant. We update the test procedure in the writing to analyze fundamentally whether a classifier does undoubtedly generously outperform another classifier.

The choice of metrics being the first and the chief stage in the software deformity prone has an extraordinary impact in the accuracy and the intricacy of the model. More the quantity of metrics in the model, progressively complex is the procedure Inclusion of insignificant metrics can make the accuracy drop extensively. Additionally, the effect of these metrics can be illogical [2]. It is conceivable that the apparently significant metrics can have less value in the software deformity prone, ascribing to some unpretentious, unanticipated variables. Things being what they are, the determination of suitable metrics is conceivable just by experimental confirmation. Remembering the serious results that the poor metrics choice can cause, we dedicate additional endeavors to deliberately choose the determinant metrics. Bug forecast can be considered as a component of metrics and the idea of this capacity remains obscure. Before, analysts have planned software deformity prone models utilizing determinants like past software deformity prone code stir number of engineers, record length, code refactoring, etc. (see Fig. 1) Subsequent to making a far reaching investigation of

the created models and methodologies, we devise a novel way to deal with gauge the software deformity prone of source code at the class level. Individuals who are taking a shot at software deformity prone for the most part apply open informational index and Artificial Intelligence (AI) techniques for developing unrivaled software deformity prone. Software deformity prone is indispensable and vital activity advantageous to give best excellence and increase the reliability of software before the software is introducing.

In Machine Learning, ML can pursue two diverse learning approaches: supervised and unsupervised Learning. The supervised learning algorithm only works with a bunch of datasets models whose names are mentioned. The Experimental results can be supposed with metrics variables of the classification task, or numerical variables of the regression task [3]. On the other hands unsupervised learning, the names of the models in the dataset models are doubtful, and the algorithm often goes for gathering models as indicated by the closeness of their attribute esteems, describing a clustering task. Supervised algorithm technique can be analyzed by classification task where every instance placed with a class, which is observed by the estimation of a unique independent attribute or basically the class attribute. The objective attribute can take on clear cut qualities, every one of them relating to a class. Every model comprises of two sections, in particular a set of predictor attribute esteems and an objective attribute esteem.

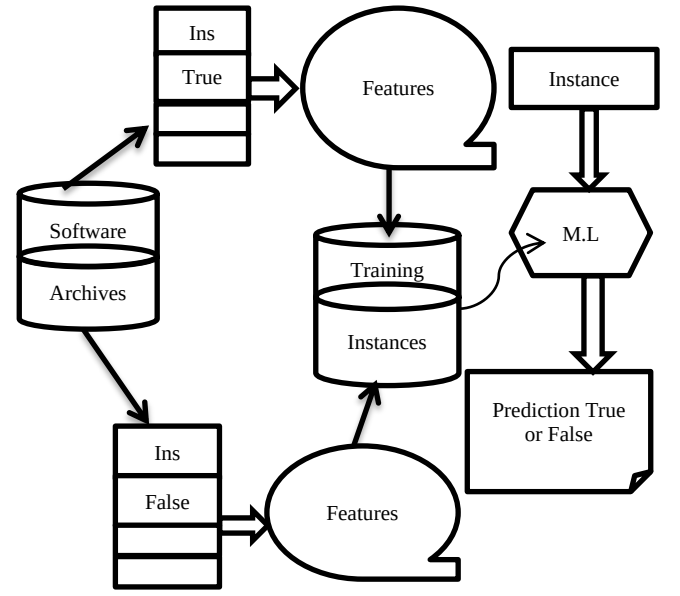

Fig. 1. Flow Chart of Software Deformity Prone Model.

II. Background

In the era of 2000, the different method metrics were considered. However, in year 2000, there were different impediments for Software deformity Prone. When any item release then it was very difficult to assure the software quality about software metrics. The Software deformity prone datasets couldn't skilled to forecast faults at any point source code which change performs. For resolving this matter, Mockus et al. gave solution datasets model for changes performs. This given solution method was famous as just-in-time (JIT) Software deformity prone datasets model [4]. Mockus proposed solution JIT model been considered advance by various looks that enhanced forecast improvement for modification occurred. Further weakness of Software deformity prone datasets model was to make an imperfection forecast datasets model for different influx task or software with couple of old data. To defeat this issue specialist had done different examinations to construct cross task Software deformity prone model. It raised issue of cross Software deformity prone recognizable proof.

In 1971, Akiyama initially lead the analysis on similar to the quantity of faults and observed source code which caused increasingly quantity of faults. He assured that many line of codes are present in huge Software deformity Prone and these line of codes LOC can measure the complexity of Software deformity Prone. After that he considered these codes as metrics. He proposed and developed primary Software deformity prone model which reliant on the LOC Metrics [5]. For this purpose that he may analyzed where LOC metric is extremely small metric and also measure the complexity of any software. Further overcome this problem, Halsted complexity metric and cyclomatic complexity was given by Halested and McCabe in 1977 and 1976. Which proposed and given individually in era of these years [6]. Once again it needs to be considered in the era of 1970s to 1980, forecast datasets model was not so good to measure the enough quantity of software forecast faults and enhanced the quality of software. This seems to be direct fitting model. This kind of fitting model gives the connection between faults and metrics. All new datasets models are also ignored by fitting model in software deformity Prone. So to overcome this limitation of failure forecast datasets model, a new proposed method given by scientist Shen et al. this proposed model reliant on linear regression. This proposed model also used to test model for new module of software.

Later, few cases were studied by Munson et al. he had been conveyed in these cases that linear regression systems isn't the exact and goof to use for test models or new model datasets. So he proposed and developed another deformity forecast datasets model. This proposed model was reliant on classification approaches. These approaches were order the

datasets model in to two sections usually safe and high hazard. This approaches also proficient and measure accuracy of 92%. These approaches also had faced few arguments and observed that it had no metrics of item located framework and having link of resources for more perfection. One article also considered for arranged framework. This article proposed by Kemerer and Chidamber in 1994. Basically both had proposed many articles set on metrics. One more deformity forecast datasets model proposed by Basili et al. in 1990 [7]. This proposed method reliant on item arranged metrics. This arranged metrics was noticeable to resolve deformity forecast datasets model but however not finally succeeds. So Zimmermann et al. had examined the issue and attempt to make cross task deformity prediction datasets model with classifying fold cross validation forecast and try to make it progressively workable. Pinzer, Taba and Zimmerman et al had contemplated and studied about current pattern of data innovation by social network observation and by network methods. They proposed new idea of Software deformity Prone modified and another was the universal Software deformity prone model.

According to the experimental examinations, a dominant part of software modules don't cause blames in software frameworks, and flawed modules are up to 20% of all the modules. On the off chance that we partition modules into two unique sorts, flawed and non-broken, most of modules will have a place with the non-defective class and the rest will be individuals from the broken class. In this manner, datasets utilized in Software deformity prone investigations are imbalanced. Accuracy parameter can't be utilized for the exhibition evaluation of imbalanced datasets [8]. For instance, a trivial algorithm, which denotes each module as non-defective, can have 90% accuracy if the level of broken modules is 10%. In this manner, specialists utilize various metrics for the validation of Software deformity prone models.

III. Computational Solution using Classification via Atttribute Selection Evaluators

Before Attribute selection is well known as feature selection, which has been studied in the era of pattern recognition for a considerable length of time. In reverse eradication, e.g., was announced in the early 1960s (Marill and Green, 1963). Kittler (1978) studies the Attribute selection algorithms that have been developed for pattern recognition. Best-first search and genetic algorithms are standard artificial intelligence systems (Goldberg, 1989; Winston, 1992). The attribute selection is the method by which each attribute in your model set is evaluated in the context of the yield variable (e.g. the class) [9]. The search method is the method by which to attempt or navigate different mixes of attributes in the model set so as to arrive on a short rundown of chosen attribute. Some Attribute Evaluator method requires the use of specific Search Methods. Attribute selection is used for decrease the dimensionality, eliminate inappropriate and redundant data. For example, the GainRatio technique used in the this research must be used with a Ranker Search Method that evaluates each attribute and records the results in a rank order. Another example is CFSSubsetEval technique used in this research must be used with Best-First methods that evaluates each attributes and rundown the results according to best-first attribute. When selecting different Attribute Evaluators, the interface may request that you change the Search Method to something compatible with the chosen technique. Both the Attribute Evaluator and Search Method techniques can be configured.

GainRation (GR) measures the analysis of the class deformity prone model sets in bits; the occurrence of an attribute and the corresponding class is exists if the principal class deformity prone model sets is existing. The predictable reduction in entropy is intensely measures [9]. One case that is filter method, which ranks one particular, attributes allowing attributing significance score for attribute selection. But (CFS) method scores and ranks subsets of attribute together, rather than single attribute.

Most techniques for attribute selection include finding the space of attributes down the subset that is well on the way to anticipate the class best. The quantity of potential attributes subsets increments exponentially with the quantity of attributes, making a comprehensive inquiry unreasonable on everything except the least complex issues. The impact of including each attribute thusly is evaluated by this measure, the best one is picked, and the strategy proceeds. In any case, if no attribute creates an improvement when added to the flow subset, the pursuit closes. This is a standard greedy inquiry methodology and certifications to discover a locally—yet not really comprehensively—ideal arrangement of attributes. Here the distinct valuations of use linked attribute to attribute evaluators such as (ReliefF, Gain Ratio, Entropy and so on.) is one kind of Ranker strategy which is used for giving ranked attributes. The parameter of attributes evaluators make placing as like (true or false) number to choose [10]. There is threshold esteems, which is only set the threshold. Because attributes can be disposed of by this threshold esteems. But attributes cannot be disposed by Default esteem. So we use each this substitute or number to select to shrink the attribute set. The classification and variable positioning is known as filter technique. This is a preprocessing stage, which have ability of the choice to predict. The almost portion of ranker method does the rank that which attributes should to be getting high or low position and allowing to select attribute in the given data indexes. Ranking of the attributes is also given by Rankers, but in other hands ranking order given by their ranking to the evaluator.

IV. Dimensionality Reduction using Attribute Evaluators PCA

PCA is basically to locate a low-dimension model data set of tomahawks that outline model data set. PCA utilizes the change of each feature to do likewise. Principal Component Analysis is an unsupervised Feature Reduction technique for anticipating high dimensional data into another lower

dimensional portrayal of the data that depicts however much of the change in the model data set as could reasonably be expected with least remaking blunder. So, this progress is achieving through comprehensive method Principal Component Analysis. Other sets of variables or values are developed by this approach which is known as Principal components and these are the conventional combination of first variables. Almost PCA are orthogonal to each other, so there is not any redundant data due to this of PCA and main reason for space of the data is also orthogonal structure in all PCA. In this manner we propose unsupervised feature selection calculations dependent on eigenvectors analysis to distinguish basic unique features for principal component.

Envision that the dimensionality of the Attribute model data set is bigger than only a few. Utilizing a PCA we would now be able to recognize what is the most significant dimensions and simply keeps a couple of them to clarify the vast majority of the difference we find in our data. Thus we can radically diminish the dimensionality of the data. In addition, it will likewise empower us to recognize what the most significant factors in the first feature space are, that contribute most to the most significant PCA. Naturally, one can envision, that a measurement that has very little changeability can't clarify a great part of the happenings and hence isn't as significant as increasingly factor dimensions. Since contains the eigenvalues of the correlation matrix, its entrances relates to the differences of the data in a provided guidance [11]. The important part is then simply the left-particular vector scaled by the standard-deviation of the data in the comparing course. In the event that we just need the primary vital segments it gets the job done to increase the model data set with simply the main lines of the right-solitary vectors.

V. Computational Solution Model Design

We have used 12 different classifiers with NASA PROMISE repository datasets model (Fig. 2). We have used 17 NASA PROMISE repository datasets models. Each datasets model has attributes and class of interest as shown in Table I. The class of interest is defective model and non-defective model. Our experiments performed on defective class model. We have used WEKA tool for performing the experiments results and analysis the observation of each experiments datasets model. Our proposed solution technique is Attribute SelectedClassifier with selected evaluators and searching method for reducing the dimensionality of training and testing data provided by defected models NASA datasets by attribute selection before being passed on these 12 classifiers. We have used four measure units to access the performance of interested class defected models whether the class of interest defected model is still defected or clean. These four measure units are Correctly Classified instances (C.C.I %), TP-Rate, F-Measure (Positive Accuracy) and ROC area under curve. We have used 10-fold cross validation for classification of datasets models. The technique AttributeSelectedClassifier is used with three evaluators and three searching methods where CFSSubsetEval, GainRatio and PCA used as Evaluators. Best first, Random Search and Rankers are used as for searching methods with AttributeSelectedClassifier.

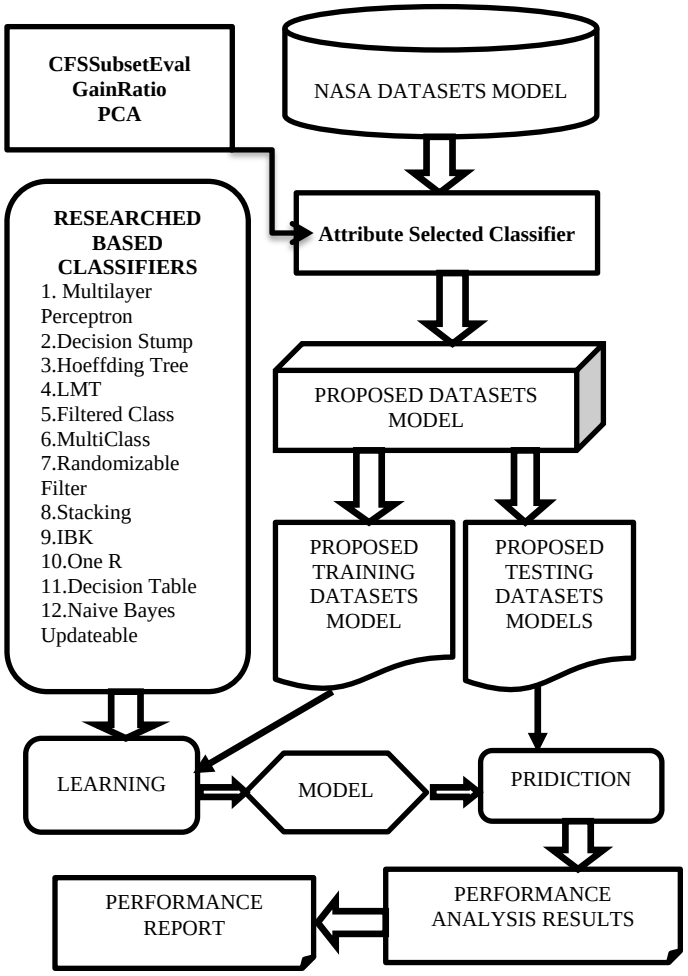

Fig. 2. Proposed Solution Model Design

TABLE. I. NASA PROMISE Repository Datasets Model

S.NO	Datasets	Attribute	Models	Defective Model	Non-Defective Model
1	AR1	30	121	9	112
2	AR6	30	101	15	86
3	AR3	30	63	8	55
4	AR4	30	107	20	87
5	AR5	30	36	8	28
6	CM1	38	327	42	285
7	JM1	22	7782	1672	6110
8	KC2	22	522	107	415
9	KC3	40	194	36	158
10	MC1	39	1988	46	1942
11	MC2	40	125	44	81
12	MW1	38	253	27	226
13	PC1	38	705	61	644
14	PC2	37	745	16	729
15	PC3	38	1077	134	942
16	PC4	38	1458	158	1289
17	PC5	39	17186	516	16670

VI. Experimental Results

The Research Experimental results and analysis are illustrated in Tables II to V and with respective Fig. 3 to 6. The above tables and following figures explains the performance of software deformity prone datasets models with proposed solution. The above tables and graphs are explained by measure units which are TP-Rate, Area under Curve, Positive Accuracy and Correctly Classified Instances. These all are analyzed by proposed solution which is AttributeSelectedClassifier. This proposed solution contains three techniques. So, all experiments results and analyses in above tables and following graphs are described by these techniques. The table shows results as No-Attribute Selection, CFSSubsetEval, GainRatio and PCA. No-Attribute Selection means, the experiments results are performed by without using any attributeselectedclassifier techniques. CFSSubsetEval, GainRatio and PCA which means that experiments results are performed by attributeselectedclassifier. We have used 12 classifiers for compare the analysis results of these techniques.

In Table II, we have analyzed Correctly Classified Instances Results performance where we have seen that overall performance of GainRatio is better than other two techniques. Hoefdding tree, LMT, Multi Class, Stacking and Decision table, these have better performance in all three techniques.

In Tables III to V, we have analyses the Area under Curve, Positive Accuracy and TP-Rate, where the ROC performance of IBK and Decision stump are decreased in all three techniques. The TP-Rate performance of Multilayer Perceptron, Filtered and One R is also decreased in all three techniques. The Positive accuracy of these three techniques is also increased specially in Hoeffding tree, Naive Bayes, Multi Class, IBK and Randomizable filtered class. Stacking has worst performance in positive accuracy and tp-rate in all over technique. In overall experimental analysis, from Fig. 3 to 6, we illustrated that CFSSubsetEval and GainRatio performance is better in almost classifiers. In case of Correctly Classified Instances performance, where Fig. 3 shows that CFS SubsetEval performance is better in all over the classifiers.

TABLE. II. Correctly Classified Instances Performance

S.NO	Name: CLASSIFIERS	NO ATTRIBUTE SELECTED C.C.1 %	CFSSubsetEval C.C.1 %	GainRatio C.C.1 %	PCA C.C.1 %
1	Multilayer Perceptro	74.61%	86.87%	89.43%	81.27%
2	Decision Stump	70.63%	86.76%	89.86%	80.45%
3	Hoeffding Tree	67.21%	87.27%	87.64%	86.87%
4	LMT	72.28%	86.72%	87.32%	86.9%
5	FILTERE	76.29%	87.2%	87.24%	80.33%
6	MULTICLASS	71.66%	87.36%	87.47%	86.37%
7	RANDOMIZABL	71.34%	83.32%	89.87%	83.33%
8	STACKING	56.12%	86.12%	86.12%	86.12%
9	IBK	61.72%	83.2%	89.02%	83.93%
10	ONE R	67.79%	86.06%	86.52%	85.64%
11	DECISION TABLE	71.05%	87.46%	87.71%	86.05%
12	Navie-Bayes-up	74.56%	85.97%	87.49%	86.25%

TABLE. III. Area under Curve Performance (ROC)

S.NO	Name: CLASSIFIERS	NO ATTRIBUTE SELECTED (ROC)	CFSSubsetEval (ROC)	GainRatio (ROC)	PCA (ROC)
1	Multilayer Perceptron	0.644	0.731	0.75	0.551
2	Decision Stump	0.672	0.665	0.673	0.651
3	Hoeffding Tree	0.574	0.594	0.599	0.564
4	LMT	0.451	0.725	0.737	0.614
5	FILTERE	0.584	0.615	0.617	0.561
6	MULTICLASS	0.625	0.76	0.765	0.758
7	RANDOMIZABL	0.625	0.626	0.724	0.675
8	STACKIN	0.458	0.658	0.558	0.458
9	IBK	0.656	0.638	0.625	0.653
10	ONE R	0.479	0.596	0.595	0.566
11	DECISION TABLE	0.654	0.642	0.636	0.566
12	Navie-Bay	0.552	0.732	0.739	0.725

TABLE. IV. F-MEASURE POSITIVE ACCURACY PERFORMANCE

S.NO	Name: CLASSIFIERS	NO ATTRIBUTE SELECTED F-MEASU	CFSSubsetEval F-MEASURE	GainRatio F-MEASURE	PCA F-MEASURE
1	Multilayer Perceptron	0.141	0.268	0.336	0.309
2	Decision Stump	0.103	0.215	0.221	0.146
3	Hoeffding	0.156	0.216	0.223	0.16
4	LMT	0.177	0.264	0.257	0.218
5	FILTER	0.166	0.253	0.263	0.168
6	MULTICLASS	0.113	0.261	0.273	0.256
7	RANDOMIZABL	0.217	0.312	0.322	0.341
8	STACKIN	0	0	0	0
9	IBK	0.158	0.333	0.325	0.356
10	ONE R	0.161	0.259	0.275	0.209
11	DECISION TABLE	0.168	0.259	0.276	0.174
12	Navie-Bayes-upd	0.18	0.38	0.397	0.304

TABLE. V. TP-RATE PERFORMANCE

S.NO	Name: CLASSIFIERS	NO ATTRIBUTE SELECTED TP-RATE	CFSSubsetEval TP-RATE	GainRatio TP-RATE	PCA TP-RATE
1	Multilayer Perceptron	0.292	0.211	0.278	0.264
2	Decision Stump	0.192	0.503	0.413	0.427
3	Hoeffding Tree	0.123	0.571	0.687	0.416
4	LMT	0.214	0.606	0.592	0.361
5	FILTERED	0.213	0.205	0.218	0.141
6	MULTICLASS	0.286	0.499	0.201	0.397
7	RANDOMIZABLE FILTER	0.301	0.488	0.509	0.333
8	STACKIN	0	0	0	0
9	IBK	0.349	0.315	0.307	0.341
10	ONE R	0.208	0.203	0.324	0.173
11	DECISION TABLE	0.208	0.197	0.216	0.117
12	Navie-Bayes-upd	0.44	0.366	0.416	0.254

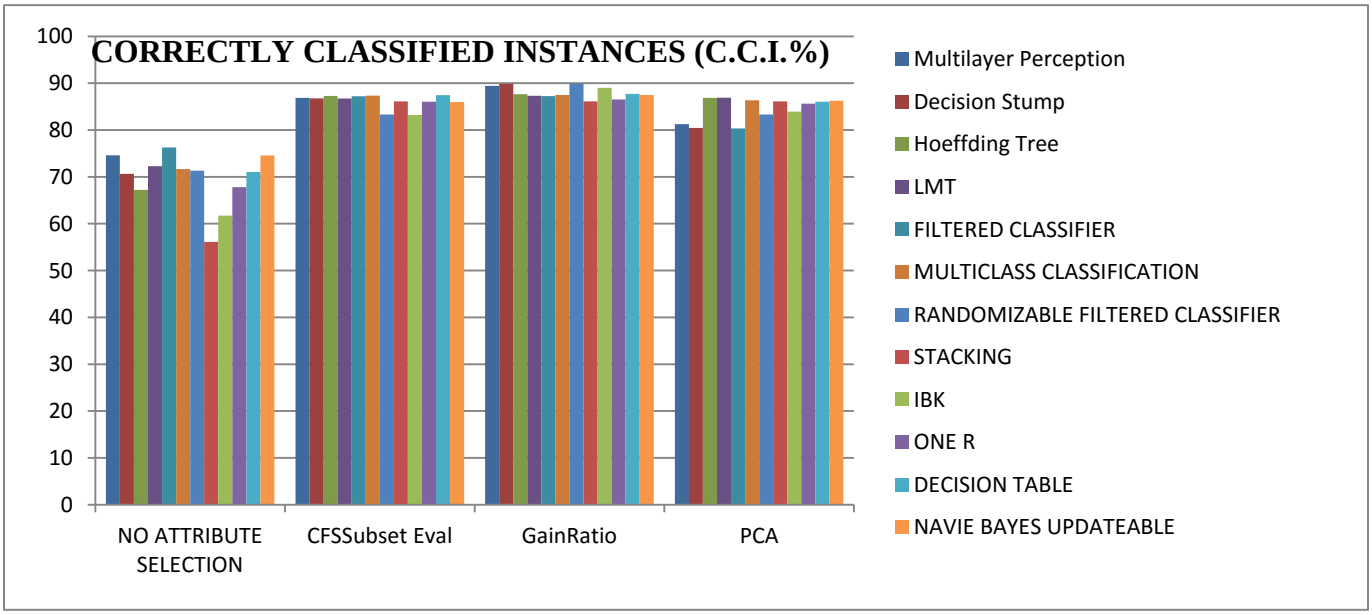

Fig. 3. Correctly Classified Instances Performance (C.C.I %).

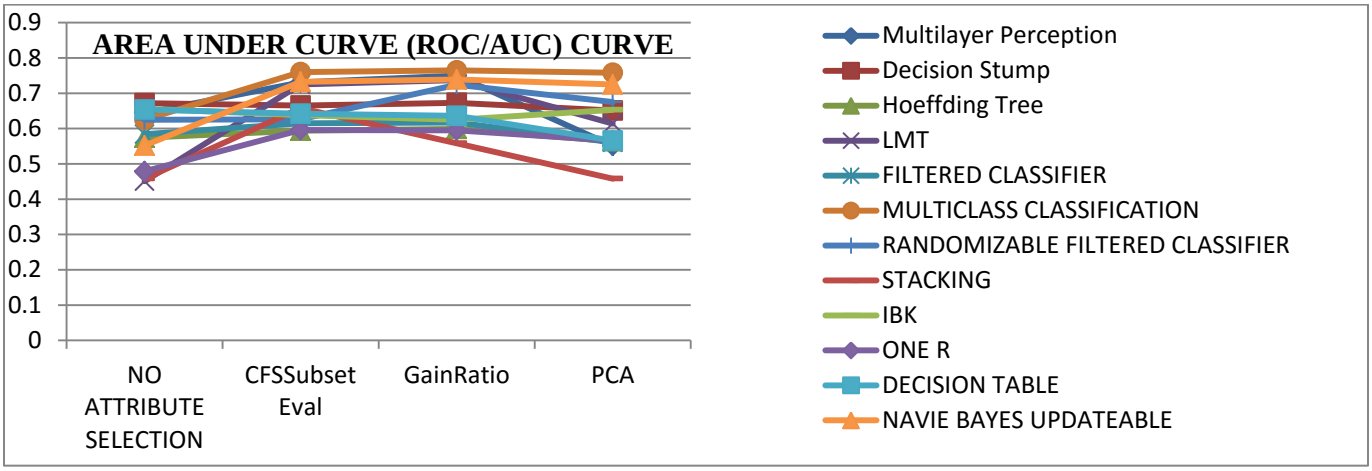

Fig. 4. Area under Curve Performance (ROC).

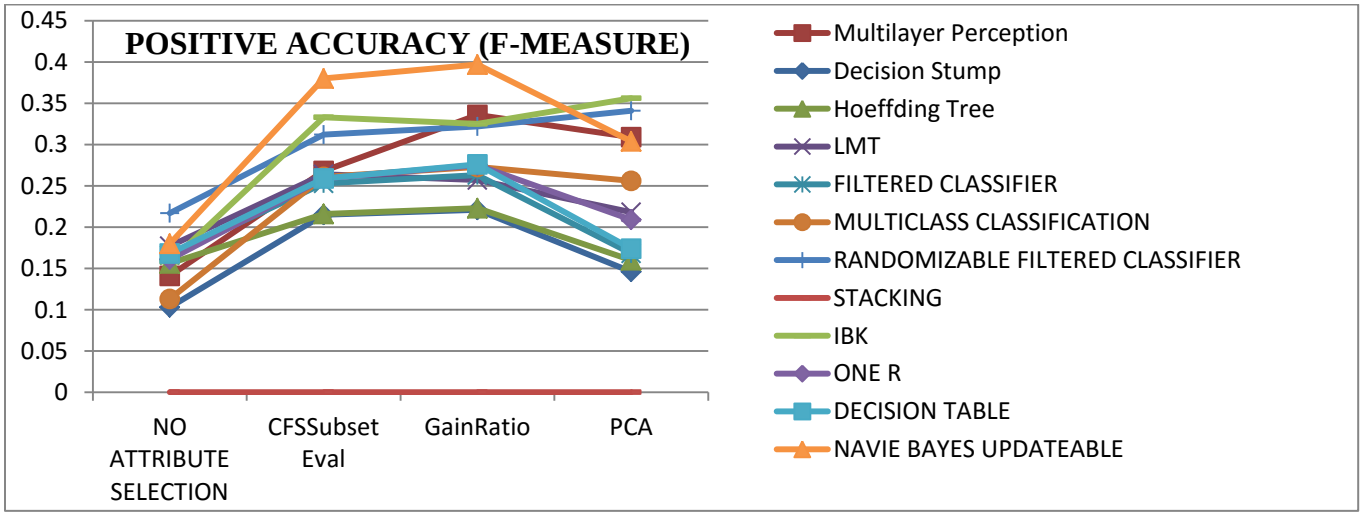

Fig. 5. Positive Accuracy F-Measure Performance.

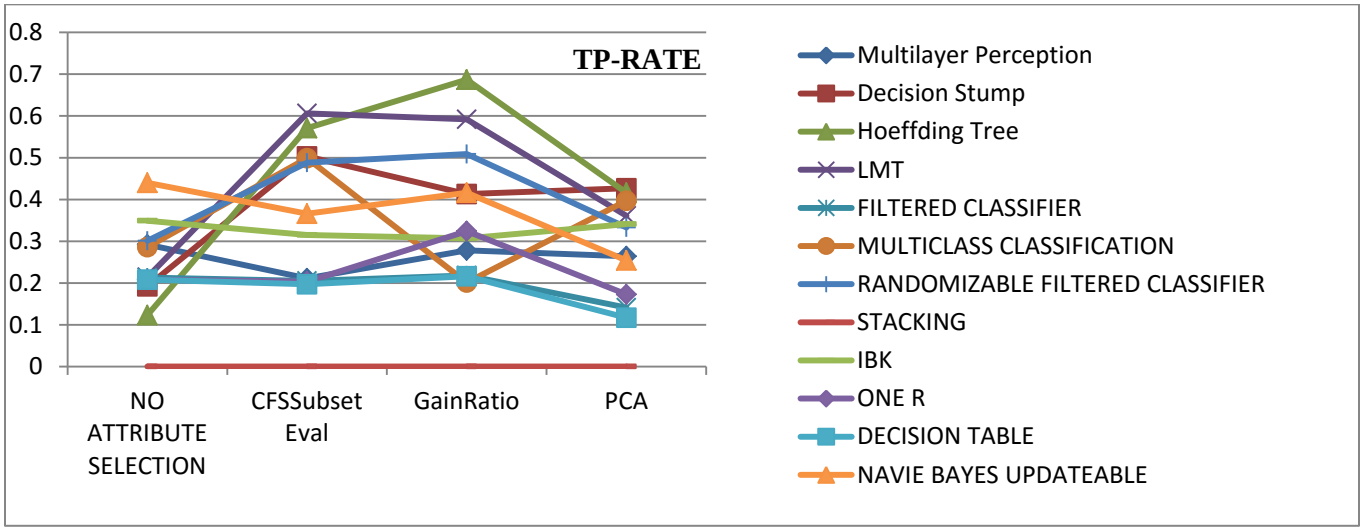

Fig. 6. TP-Rate Performance.

VII. CONCLUSION

Software Deformity Prone datasets models are widely used with different evaluation parameters which easily comparing the experimental results and analysis with old research studies work. We investigate 17 NASA PROMISE repository datasets models with proposed solution used Attribute Selected Classifier. We have used 12 different classifiers for analysis the performance of TP-Rate, Positive Accuracy, ROC Curve and Correctly Classified Instances. Where we have analyzed that CFSSubsetEval and GainRatio performance is better in almost classifiers. Hoefdding tree, Navie Bayes, MultiClass, IBK and Randomizable filtered class increased performance in Positive Accuracy in all techniques. Stacking has worst performance in positive accuracy and tp-rate in all over technique.

Our future work will be analysis of class imbalance problem with the help of linear regression and rule class attribute method, where we will overcome the problem of over-generalization datasets models.

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Detecting Inter-Component Vulnerabilities in Event-based Systems

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***Abstract*—Event-based system (EBS) has become popular because of its high flexibility, scalability, and adaptability. These advantages are enabled by its communication mechanism—implicit invocation and implicit concurrency between components. The communication mechanism is based on non-determinism in event processing, which can introduce inherent security vulnerabilities into a system referred to as event attacks. Event attack is a particular type of attack that can abuse, incapacitate, and damage a target system by exploiting the system's event-based communication model. It is hard to prevent event attacks because they are administered in a way that does not differ from ordinary event-based communication in general. While a number of techniques have focused on security threats in EBS, they do not appropriately resolve the event attack issues or suffer from inaccuracy in detecting and preventing event attacks. To address the risk of event attacks, I present a novel vulnerability detection technique for EBSs that are implemented by using message-oriented middleware platform. My technique has been evaluated on 25 open-source benchmark apps and eight real-world EBSs. The evaluation exhibited my technique's higher accuracy in detecting vulnerabilities on event attacks than existing techniques as well as its applicability to real-world EBSs.**

Keywords*—Event-based system; program analysis; software security

I. Introduction

Event-based systems (EBSs) implemented by using MOM platforms are widely used. They are implemented in various types of systems such as web apps or SOA-based systems by using different types of MOM platforms such as Prism-MW [1], Java Message Service [3], and Siena [10]. EBSs have become popular because of its high flexibility, scalability, and adaptability. These advantages are enabled by its reliance on implicit invocation and implicit concurrency. Specifically, in EBSs, components may not know the consumers of the events they publish, nor do they necessarily know the producers of events they consume. However, this communication mechanism is based on non-determinism in event processing, which can introduce inherent security vulnerabilities into a system referred to as event attacks. For example, developers may build EBSs by utilizing externally developed components that contain malicious code, and users may use those EBSs comprising malicious components. For those cases, malicious components can launch unintended behaviors through event communication, such as eavesdropping on events to steal sensitive information or exploiting the information in events to hijack the system's functionalities.

Existing system analysis techniques neither focus on event attacks nor correctly detect vulnerabilities across components [5,6,7,23]. Specifically, existing vulnerable-flow analysis techniques do not support implicit invocation between components and are not scalable to analyzing systems comprising large numbers of components [6,7,12]. While a large body of research has studied detecting vulnerabilities that expose Android apps to event attacks [9,11,12,13], they cannot be directly applied to other types of EBSs, because Android uses its system-specific communication model, APIs, and component life-cycles. Thus a generalized solution is required to protect other types of EBSs.

To overcome aforementioned challenges and the shortcomings of the existing approaches, I designed a technique that automatically detects target EBS's vulnerabilities that expose the system to event attacks. My solution statically inspects target EBS in order to identify security vulnerabilities that expose the system to event attacks. It performs vulnerable-flow analysis and pattern matching on event communication channels between components. My technique is distinguished from prior works because (1) it detects potential risks of event attack in EBSs more accurately than existing techniques, (2) it supports multiple types of MOM platform, and (3) it enables a scalable analysis of EBSs comprising a large number of components and methods.

This paper makes the following contributions: (1) I proposed a novel technique that identifies security vulnerabilities from multiple types of EBSs; (2) I developed a prototype tool that implements the proposed technique; (3) I provided the results of evaluations that involve real-world EBSs and comparable techniques. Section 2 illustrates event attacks in EBSs, which motivate my research. Section 3 details my approach and Section 4 presents the evaluations of my technique. A discussion of related work is provided in Section 5, and my conclusions are presented in Section 6.

II. Motivating Example: Web Applications

In this section, I will present a simplified example of event attack which can be launched on event-based web apps. Fig. 1 and 2 illustrate eavesdropping attack. An app App1 follows event-based communication model and is implemented by using Java Message Service [3], a Java MOM platform for message-based communication between components. App1 is corrupted to contain an unintended component Mal (in Fig. 2) so that event attacks can be launched. Fig. 1 and 2 show where App1's vulnerability resides. In this app, all events are published through "CustomTopic".

```
1  public class Vic {
2   ...
3  String s = getSensitiveInfo();
4  Topic topic = (Topic)ctx.lookup("CustomTopic");
5  TopicConnection con = factory.createTopicConnection();
6  TopicSession session = con.createTopicSession(false, Session.AUTO_ACKNOWLEDGE);
7  TopicPublisher publisher = session.createPublisher(topic);
8  Message e1 = session.createMessage();
9   e1.setJMSType("TextMessage");
10  e1.setName("ReplyInfo");
11  e1.setStringProperty("Sensitive", s);
12  publisher.publish(e1);
13  }
```

Fig. 1. Component Vic in App1.

```
1   public class Mal {
2   ...
3   String m;
4   Topic topic = (Topic)ctx.lookup("CustomTopic");
5   TopicConnection con = factory.createTopicConnection();
6   TopicSession session = con.createTopicSession(false,Session.AUTO_ACKNOWLEDGE);
7   TopicSubscriber subscriber = session.createSubscriber(topic);
8   subscriber.setMessageListener(new MessageListener(){
9    protected void handleMessage(Message e2){
10  if (e2.getName().equals("ReplyInfo")){
11     m = e2.getStringProperty("Sensitive");
12  }}}
```

Fig. 2. Component Mal in App1.

Component Vic in App1 (in Fig. 1) publishes an event e1 through CustomTopic without any particular protection such as access restrictions. e1 has two attributes— one with the name “Name” (whose value is “ReplyInfo”) and one with the name “StringProperty” (whose value is “Sensitive”)—while containing sensitive information (i.e., s). By listening to “CustomTopic” and declaring attributes “ReplyInfo” and “Sensitive”, Mal can eavesdrop on the event sent from Vic and obtain the sensitive information.

As shown in this example, since event attacks appear to be ordinary event interactions, existing malware inspection techniques, especially the techniques that rely on signature-based detection [23], may not be able to detect event attacks. Moreover, since publishing and consuming events can be processed via ambiguous interfaces, existing flow-analysis techniques will be unable to accurately analyze implicit invocation between components. Furthermore, since routing event is performed in an invisible and non-deterministic way, it is difficult to expect when and where the event attacks are actually launched.

III. Solution

My proposed solution basically considers three main challenges as follows: (1) ambiguous event communication channels: EBS’s inherent attributes hamper the extraction of event communication channels via which events are exchanged between components. Specifically, implicit invocation between components makes it difficult to determine where each event will flow into, and EBS’s event interfaces do not explicitly reveal the events to be consumed. Furthermore, depending on the types of MOM platform, different event interfaces can be used. To handle this, my technique leverages Eos [4], a technique that statically extracts event types and their attributes based on the characteristics of underlying MOM platform; (2) scalable flow analysis: To check whether sensitive data leaks or unintended access to sensitive functionality can be launched, control-/data-flow analysis on methods in each component is required. However, in case when an EBS comprises a large number of components and methods, flow analysis on every method in the EBS may not be scalable. According to prior research. [8], on average, EBSs contain over 35 methods to be analyzed, which could consume hours for a real-world EBS. Although several flow-analysis techniques have been proposed for Android apps [12,19], considering the fact that mobile platforms limit the size of apps, those techniques may not scale with large-scale EBSs containing methods with larger size and higher complexity. My technique provides a size reduction algorithm which enables its analysis to scale well with identifying vulnerabilities from large-scale EBSs; (3) inconstant distinction of components. Event attacks are launched across the components that have different trust level. Although Android uses a consistent mechanism for distinguishing among the trust levels of app components (i.e., each “app” has different trust level), other EBSs may use different types of distinction depending on their system configuration. For example, the trust level of externally-developed components can be different from that of component developed in-house. To handle this, my technique introduces the concept of trust boundaries. A trust boundary is defined as a unit for dividing components based on each component’s

trust level. Components that have the same trust level belong to the same trust boundary, and a trust boundary can be set per each component as well as a group of components.

My solution operates in three phases—Extraction, Reduction, and Identification—and uses three types of inputs: the target EBS's (1) implementation, (2) configuration, and (3) sensitive APIs. The configuration includes the information regarding the underlying MOM platform (i.e., the methods for event communication and the base class for events) and trust boundaries. The information of underlying MOM platform can be derived from the API specification of the platform, which only needs to be identified once per platform. Considering the existing platforms, such information has been publicly accessible. Trust boundaries can be easily derived by clustering components based on a developer's trust level regarding each component. While a set of sensitive APIs relies on the expectation that developers can provide accurately, it is fairly straightforward to identify them. Because so far as the components developed in-house are concerned, they might know particular APIs that handle important data or sensitive functionalities. Furthermore, even if a developer is not fully knowledgeable about the sensitive APIs in the target system, she can refer to the existing sets of APIs [2] which are generally considered as sensitive. According to the results of evaluation in Section 4, relying on setter and getter methods which are generally considered as sensitive, indicated a fairly high precision (=85.67%) in identifying vulnerabilities. In the remainder of this section, I will discuss each of three phases in detail.

Extraction - In this phase, target system's implementation is inspected in order to extract two different information: (1) The first information includes published event types (PET) and consumed event types (CET) accessed by each component, which can be used to infer event communication channels between components [8]. By using static flow-analysis on the target system's implementation, every component's PET and CET are extracted along with corresponding attributes from the system implementation. In Fig. 1, an example of PET published at line 12 is {(Name: "ReplyInfo"), (StringProperty: "Sensitive")}; (2) The Second information is the location where each sensitive API is accessed or called. For each method in a given list of sensitive APIs, the components where the method is called are identified along with their location in the system implementation.

Reduction-To identify vulnerable event communication channels, both inter- and intra-component flows are considered by combining the extracted event types with each component's control-flow graph (CFG). However considering a large-scale EBS, it may not be scalable to generate and traverse every component's CFG. To address this, we build an event flow graph (EFG), which provides a macro perspective of target EBS (see Fig. 3), and examines the EFG in order to prune the components that are unnecessary for subsequent analyses.

In an EFG, components are connected by the edges that represent event communication channels between pairs of components. An edge is determined by matching PET and CET, while having a direction to which an event is being sent. For the component where a sensitive API is called, my solution checks if its sensitive API is reachable from or to its event interfaces—consuming event interface (CEI) and publishing event interface (PEI)—via its call graph (CG). If yes, the component is labeled as a sensitive component (see Fig. 3). The components that form an event communication channel across trust boundaries are labeled as boundary components. If a boundary component's PEI for event communication across trust boundaries is reachable from its CEI or sensitive API via CG, its attribute is set to be outflow-boundary (OB). Conversely, if its CEI for event communication across trust boundaries is reachable to its PEI or sensitive API via CG, its attribute is set to be inflow-boundary (IB).

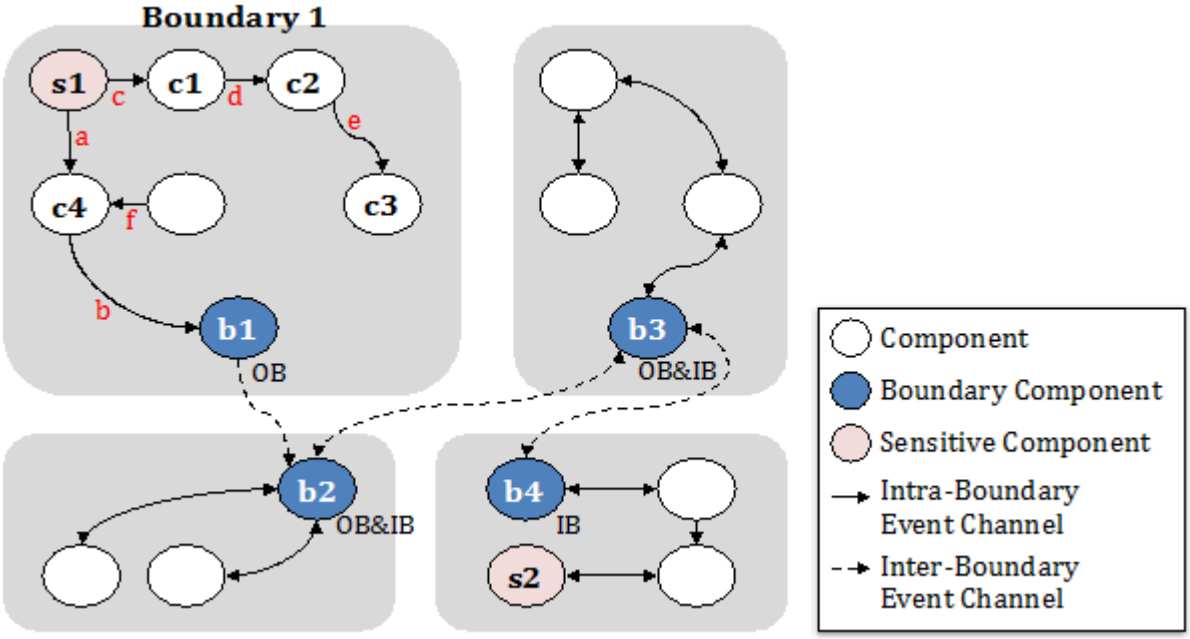

Fig. 3. An Event Flow Graph.

Algorithm 1. Identification of Vulnerable Communication Channels

Input: $G \Leftarrow$ an EFG
Output: $VulCF \Leftarrow$ a set of vulnerable event communication channels
1 Let S_G be a set of sensitive components in G
2 Let OB_G be a set of outflow-boundary components in G
3 Let IB_G be a set of inflow-boundary components in G
4 Let SM_c be a set of sensitive methods in a component $c \in G$
5 Let $l = [c1, c2, ... cn]$ be a list of connected components from component $c1 \in S_G$ to component $cn \in OB_G$ or from component $c1 \in IB_G$ to component $cn \in S_G$
6 Let $t \in (PET_c \cup CET_c)$ where $\forall c \in G$
7 **foreach** $l \in G$ **do**
8 **if** $((c1 \in S_G) \wedge (cn \in OB_G))$ **then**
9 **foreach** $s \in SM_{c1}$ **do**
10 $t \Leftarrow$ *identifyFlow*($c1$, s, PEI_{c1}, "out", l.remove($c1$))
11 add *getOutFlowChannel*(t) to *VulCF*
12 **if** $((cn \in S_G) \wedge (c1 \in IB_G))$ **then**
13 **foreach** $s \in SM_{cn}$ do
14 $t \Leftarrow$ *identifyFlow*(cn, s, CEI_{cn} , "in", l.remove(cn))
15 add *getInFlowChannel*(t) to *VulCF*
16 return *VulCF*

My solution prunes the components that are not associated with vulnerable event communication. For example, in Fig. 3, component s1 publishes two different types of events (i.e., a and c) each of which initiates different subsequent event communication (i.e., b and d-e, respectively). Considering the fact that event attacks exploit (1) event communication across trust boundaries and (2) event communication that flows into or from sensitive APIs, event communication channels for c, d, and e are not essentially vulnerable to event attacks, because they are not involved in the event communication across trust boundaries. Thus, the components that are connected with those event channels are removed (i.e., components c1, c2, and c3) from EFG in order to reduce the overhead in subsequent flow analyses.

Identification-Vulnerable event communication channels are identified by implementing Algorithm 1 on the pruned EFG. Algorithm 1 iterates over each list of connected components (i.e., l in G), which directs from a sensitive component to a boundary component or reverse (lines 7-15). Two cases are considered depending on the direction of l:

(1) For l which directs from a sensitive component to an outflow-boundary component (lines 8-11), Algorithm 1 checks if an intra-component flow exists between a sensitive methods and PEI of *c1* (=the starting component of l) by calling *identifyFlow* with the flag as "out" (line 10). To illustrate this case, consider the component Vic in Fig. 1. Since Vic is a sensitive component and an out-flow boundary component, Algorithm 1 checks if an intra-component flow exists between its sensitive method *getSensitiveInfo* and its PEI publish by calling *identifyFlow*. *identifyFlow* checks if a given component contains an intra-component flow between given two methods (i.e., *m1*: *s* and *m2*: PEI_{c1}). In case when a given flag is "out", it inspects every node in the CFGs of *m1* and *m2*, and checks if a node in *m2* is dependent on a node in *m1*. If yes, it recursively checks an intra-component flow from CEIs to PEIs of subsequent components in *l*. If the flows exist throughout every component in *l*, it returns PET which can be published via *m2*; Otherwise it returns null. For the reverse case when flag is "in", it checks the flow from nodes in *m2* to node in *m1*, and recursively identifies intra-component flows from PEIs to CEIs of subsequent components in *l*. If the flow exists through every component in *l*, it returns CET, which can be consumed via *m1*; Otherwise, it returns null. If *identifyFlow* returns PET (i.e., *t*) which is not null, Algorithm 1 identifies the event communication channel where the returned PET is published by calling *getOutFLowChannel*, and add the channel to *VulCF*, a set of vulnerable event communication channels (lines 10-11). Coming back to the example in Section 2, since Vic contains an intra-component flow from *getSensitiveInfo* to publish, the PET (i.e., {(Name: "ReplyInfo"), (StringProperty: "Sensitive")}) will be returned by Algorithm 1. Finally, the communication channel between Vic and Mal will be added to *VulCF*.

(2) The second case is for l which directs from an inflow-boundary component to a sensitive component (lines 12-15). Algorithm 1 checks if an intra-component flow exists between a sensitive method *s* and CEI of *cn* (=the last component of l) by calling *identifyFlow* with the flag as "in" (line 14). If *identifyFlow* returns CET (i.e., *t*) which is not null, Algorithm 1 identifies the event communication channel where the returned CET is consumed by calling *getInFlowChannel*, and add the channel to *VulCF* (line 15).

My solution also performs pattern analysis on the event communication channels in EFG based on the previously identified patterns [9]. Four different patterns are considered as follows: (c: a component, T: a trust boundary, $x \Rightarrow y$: an event communication channel exists from x to y).

(1) For components c1 and c2 $\in$ T1, c3 $\in$ T2; c1 = c2 = c3: $(c3 \Rightarrow c2) \wedge (c1 \Rightarrow c2)$
(2) For components c1 and c2 $\in$ T1, c3 $\in$ T2; c1 = c2 = c3: $(c1 \Rightarrow c3) \wedge (c1 \Rightarrow c2)$
(3) For components c1 $\in$ T1; c2 and c3 $\in$ T2; c1 = c2 = c3: $(c1 \Rightarrow c2) \wedge (c2 \Rightarrow c3) \wedge \neg(c1 \Rightarrow c3)$
(4) For components c1 and c2 $\in$ T1, c3 $\in$ T2; c1 = c2 = c3: $(c1 \Rightarrow c2) \wedge (c2 \Rightarrow c3) \wedge \neg(c1 \Rightarrow c3)$

The patterns are based on the assumption that event communication within the same trust boundary is intended access, but event communication across the boundaries can be unintended access from a malicious component. Specifically, in case of the pattern (1), c3 $\Rightarrow$ c2 can be spoofing. For the pattern (2), c1 $\Rightarrow$ c3 can be interception or eavesdropping. For the pattern (3) and (4), c1 $\Rightarrow$ c2 $\Rightarrow$ c3 can be confused deputy or collusion. If a given EFG contains event communication channels that match any of these patterns, the corresponding channel(s) to *VulCP* (i.e., a set for vulnerable event communication channels) are returned. Finally, all the identified event communication channels in *VulCF* and *VulCP* are returned. While the channels belonging to both sets can be considered as the most vulnerable, other ones also need to be inspected and protected in order to minimize the threats of event attacks in a target EBS.

IV. Evaluation

I have implemented the prototype of my solution as a stand-alone Java app which combines approximately 2,000 newly written SLOC with the off-the-shelf tools, Eos [4] and Soot [21]. Eos is used in the extraction phase to extract PET and CET from target EBS. Soot is used to generate CGs and CFGs of the components within a target EBS. The prototype was empirically evaluated in terms of its accuracy, applicability, and performance in detecting vulnerabilities from a target EBS's byte-code.

A. Accuracy

This evaluation targeted vulnerability detection tools for web apps, because they fall under a particular type of EBS which can be implemented by using MOM platforms. Among the state-of-the-art static analysis tools for detecting security vulnerabilities in web apps, three tools were executable while supporting Java-based systems: Xanitizer [7], Owasp Orizon [6], and SonarQube [5]. I evaluated my prototype's accuracy in identifying vulnerable event communication channels by comparing its results against those three tools.

Since existing test benchmarks for web apps neither target EBSs nor event attacks, I have created a test benchmark for evaluating security analysis techniques for EBSs. To minimize internal threats to the validity of results, I asked graduate students at USC to build a set of apps that implement event attacks based on the published literature [9]. They built 20 distinct event-based apps by using two representative types of MOM platforms (10 apps for each): (1) Java Message Service [3], the widely adopted Java-oriented middleware; and (2) Prism-MW [1], a research-off-the-shelf middleware platform for distributed software systems. Every app was designed to contain a malicious component that had the sole purpose of launching an event attack. The benchmark also comprises five "trick" apps containing vulnerable but unreachable components, whose identification would be a false warning. This yielded a total of 25 event-based apps containing 20 vulnerable event communication channels.

I ran the three tools on my test benchmark and measured their (1) precision, i.e., identified vulnerabilities that were actually vulnerable to event attacks, and (2) recall, i.e., the ratio of identified vulnerabilities to all those exposed to event attacks. My prototype detected vulnerable event communication channels with 100% precision and recall, correctly ignoring all "trick" cases. However, other tools (i.e., Xanitizer, Owasp Orizon, and SonarQube) were unable to find any of the vulnerabilities related to event attacks from the benchmark. Specifically, Xanitizer did not return any vulnerability. While Owasp Orizon and SonarQube reported some security warnings (e.g., potential dangerous keyword in the method), they are not directly related to the vulnerabilities caused by event attacks. This is primarily because these three tools neither target event attacks nor support inter-component flow analysis.

B. Applicability

To assess if my solution is applicable to real-world EBSs, I selected eight EBSs from the test suite which have been used in evaluating prior research [4]. While all subject systems are implemented in Java, they are from different app domains (e.g., game, simulator, and chat system), of different sizes (5K-247IK SLOC), and use different underlying mechanisms (e.g., JMS [3], Prism-MW [1], and REBECA [16]) for event communication. Since the list of sensitive APIs and trust boundaries were not provided for those systems, I have used the configuration that every 'getter' or 'setter' method was a sensitive method and every component belonged to different trust boundaries. According to the well-known sensitive API list for Android [18], 81% of sensitive methods are eight getters or setters (getter: 97%, setters: 65%), which implies that getters and setters are more likely to be sensitive to security attacks compared to other methods. However, it is important to note that this does not necessarily meant that all getters and setters are always sensitive methods. Among the eight subject systems, my prototype flagged 25 vulnerable event communication channels in three systems (Dradel: 12, ERS: 11, KLAX: 2). On average, the precision of result was 85.67% (Dradel: 75%, ERS: 82%, KLAX: 100%). Every false positive was caused by the prototype's inaccuracy in identifying control-flows between sensitive methods and event interfaces. For those three systems, Xanitizer reported 83 security warnings such as "may expose internal representation by returning reference to mutable object" and "IO Stream Resource Leaks" (Dradel: 6, ERS: 62, KLAX: 15). However only seven of them (8.43%) were related to the vulnerabilities that expose the system to event attacks. Owasp Orizon and SonarQube returned 13 (Dradel: 9, ERS: 1, KLAX: 3) and 95 (Dradel: 17, ERS: 73, KLAX: 5) implementation bugs, respectively, indicated as "empty catch detected" and "found potential dangerous keyword". But none of them were related to the vulnerabilities that expose the system to event attacks. Those three tools also did not return any such vulnerability from the other five subject systems. Although my prototype outperformed the three tools in this evaluation, it is to be noted that they detected additional types of vulnerabilities my prototype does not target.

I also tested my prototype on the event-based apps comprising different numbers of components. I created four distinct apps by adding different numbers of components (i.e., 25, 50, 75, 100, respectively) to an app randomly selected from my benchmark. To check the prototype's best-case performance overhead, each of the added components is designed to have a minimized architecture—containing one method for communicating with at most two other components (55 SLOC)—which would induce the shortest analysis time while connected with other components. The size of the apps spanned 2.8K-7K SLOC. None of the added components are involved in the vulnerable event communication channels so that they can be pruned in Reduction phase. Then I measured the analysis time for each app both "with" and "without" the Reduction phase. The result (see Fig. 4) indicates that as the number of added components increased, the difference of analysis time between "with" and "without" Reduction phase also increased. This result confirms that my solution minimizes the potential overheads in its analysis by introducing the pruning operation. Considering the fact that the added components are designed to have a minimized architecture, the effectiveness of pruning will drastically increase in the case of large-scale EBSs comprising a number of components with higher complexity.

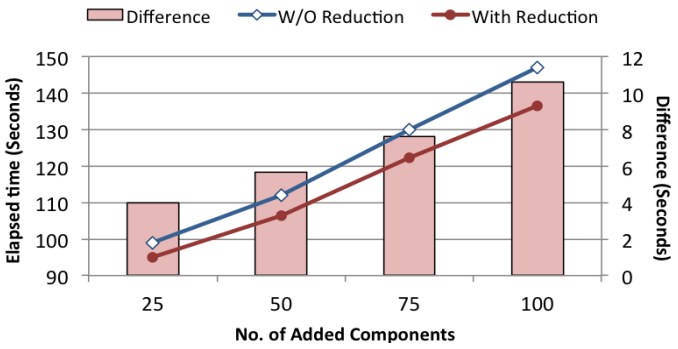

Fig. 4. Performance on different Number of Components.

V. Related Work

Several approaches have targeted the security in EBSs [15,17,20,22,25]. Simeon et al. [25] examined the security vulnerabilities of event-driven systems and defined the conditions that produce them. In general, existing security solutions for EBS employ encryption, static code analysis, and/or runtime access control techniques.

Encryption is widely used technique for securing not only general software systems, but also EBSs. EventGuard [22] proposes encryption for publish/subscribe systems in which each component encrypts events through event broker network. Publishers sign events and encrypt them with a random key, while the signature itself is encrypted with a topic-specific key and is attached to the event. However, encryption techniques increase the risk of compromised keys and may cause unacceptable performance overhead. Furthermore, key distribution is in appropriate when it is not determined which component will comprise the system.

Static code analysis is a popular technique for inspecting security flaws in target systems. SABER [14] is a static analysis tool that detects common design errors based on the instantiations of error pattern templates. Andromeda [27] inspects data-flow propagations on demand, while supporting apps written in Java, .NET, and JavaScript. Xanitizer [7] statically detects security vulnerabilities such as injections and privacy leaks by using taint-flow analysis. Owasp Orizon [6] is a source code security scanner designed to spot vulnerabilities in J2EE web apps by using pattern matching. SonarQube [5] is an open source platform for inspection of code quality to detect security vulnerabilities.

Runtime access control is another popular technique for securing EBSs. Alex et al. [24] proposed a policy model and framework for content-based publish/subscribe systems. DEFCon [26] is a middleware that applies an information flow control model which tracks the event flows through a complex, heterogeneous event processing system and constrains undesirable event flows that could potentially violate security policy. However, aforementioned techniques are more focused on other types of security issues than event attacks. Furthermore, since those techniques do not fully support event-based communication model, they may suffer from inaccuracy and scalability problems in analyzing large-scale web apps comprising a number of components.

VI. Conclusion

While event-based communication model enables highly decoupled, scalable, and easy-to-evolve systems, the non-determinism in event processing can be exploited by event attacks. Existing solutions for general software systems cannot be directly applied to resolve event attacks because they do not support event-based communication model. Furthermore, existing security solutions targeting EBSs do not appropriately resolve event attacks or suffer from inaccuracy in detecting event attacks.

To minimize the risk of event attacks, this paper presented a novel vulnerability detection technique for EBSs that are implemented by using MOM platforms. My technique statically analyzes vulnerabilities by examining inter-component flows and event communication patterns. It improves upon existing techniques in detecting vulnerabilities that expose the system to event attacks from a given EBS, while supporting multiple types of MOM platforms and increasing the coverage, accuracy, and scalability of vulnerability detection. My empirical evaluation demonstrates that my technique is more accurate in identifying vulnerable event communication channels from 33 EBSs compared to the state-of-the-art vulnerability detection techniques for web apps. The result of performance analysis shows that my technique is scalable to large-scale EBSs.

Future studies can focus on building a runtime-access controller which controls runtime event communication based on the statically-analyzed vulnerabilities. Also I can apply a visualization technique which can display the identified vulnerabilities between components in order to help engineer's understanding.

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Towards the Adoption of Smart Manufacturing Systems: A Development Framework

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***Abstract*—Today, a new era of manufacturing innovation is introduced as Smart Manufacturing Systems (SMS) or Industry 4.0. Many studies have discussed the different characteristics and technologies associated with SMS, however, little attention has been devoted to study the development process when establishing new SMS. The study's objective is to propose a development framework that increases the adoption and awareness of Industry 4.0 among manufacturers and aids decision-makers in designing better SMS capabilities. The framework consists of three phases, iterative process of application modelling; evaluation to ensure optimal configuration and adoption; and finally implementation. The proposed framework is hoped to assist the industries' management in planning for the adoption of technology, in establishing SMS or assessing the need in existing ones. Indirectly, more industry will gain the benefits as a support for their initiatives to transform into Industry 4.0.**

Keywords—Component; smart manufacturing; industry 4.0; development framework; simulation-based evaluation

I. INTRODUCTION

Smart Manufacturing Systems (SMS) refers to communication and computing technologies that enable all manufacturing system's components to be digitally connected and data analytics-driven, thus achieving intelligent coordination. It comes with several significant benefits such as cost reduction, higher productivity, resources efficiency, product customization, and minimizes negative environmental impacts.

The increasing demand of digitally connected machines and knowledge-based manufacturing systems indicates the continuing and rapid growth of SMS [1]. government investments by industrialized nations and developing countries in smart manufacturing adoption that significantly increased for the last few years contributes the growth of SMS. [2]. However, the adoption and awareness of Industry 4.0 among manufacturers in Malaysia is still low compared to other developing countries.

According to IM BizWatch [3], 70-80% of Malaysian industries are still wedged in the second industrial era while a majority of the neighboring countries and beyond are already building the bridge from Industry 3.0 to 4.0 [3]. Malaysian Investment Development Authority (MIDA) has reported that Malaysia is working hard to transition the industry bodies towards the adoption of automation and smart manufacturing concepts and technologies as this sector contributes almost 80% to the GDP [4]. The Ministry of International Trade and Industry (MITI) strategizes and plans to move forward in the adoption of smart manufacturing and Industry 4.0 in Malaysia [4]. Thus, new and innovative methods are crucially needed to adopt SMS for the nation and convince industry players to invest in this sector.

Many studies have discussed the different characteristics and technologies associated with SMS [5]-[17]; however, little attention has been devoted to study the development process challenges when establishing new SMS [18]-[20] that requires pre-implementation planning and assessment leading to minimized operational cost and time, as well as efficient machine's utilization. The first main component of the process is system configuration. System configuration involves identifying required machines, their quantities, and the workflow between machines [19], as well as the required technologies such as IoT, Big Data, Cloud computing, and AI techniques. Good configurations contribute towards the overall success of SMS projects, while poor configurations may cause late or over budgeted projects as configuration is the first phase in establishing SMS and any defects will result in failure that requires re-work in all phases.

Two different models of SMS configuration have been identified from the literature: queuing model and multi-criteria decision making model [36]-[40], [53], [54]. The queuing model enables manufacturer to evaluate the throughput, work in process, and lead times. While multi-criteria decision making models is used to determine the configuration of the SMS. However, these two models are not sufficient to solve the configuration problems due to an absence of an integrated framework that can consider different scenarios based on the market demand [19] [26]. The integrated frameworks could include other AI techniques such as agent-based modeling and simulation [56]-[58] where agents are designed to handle each resource autonomously [45], [46], [53], [55], [60], which offer flexibility for each resource to collaborate/coordinate/negotiate with each other to achieve the desired goal efficiently [47], [48], [51], [52].

Modelling and simulation study plays an important role in the selection of a particular configuration and system evaluation prior implementation [21]-[23], [49], [50]. To ensure the efficient achievement of Smart Manufacturing realization, Mittal et al. [21] includes a simulation in their action roadmap. According to SME Corp Malaysia [23], of which the first and main pillar is the simulation part that constitute the nine pillars of SMS. Therefore, a simulation tool can assist in specifying the right configuration of a particular

SMS project [19]. A Simulation is useful when the phenomenon to be studied is not directly accessible or is difficult to observe directly [24]. The idea of experimenting on models rather on the real system is not something new. For example, when an architect plans to investigate the behavior of a wind tunnel on a tower block model, they experiment on the model since the cost of experiment on a real tower block is too excessive. Thus, experimenting with simulation models as one way to obtain results and deriving the behavior of a model analytically is usually paramount because it provides information about how the model behaves given a range of inputs [25].

Therefore, in this study, we propose a development framework that increases the adoption and awareness of Industry 4.0 among manufacturers and aids decision-makers in designing better SMS capabilities. The framework consists of three phases, iterative process of application modelling; evaluation to ensure optimal configuration and adoption; and finally implementation. The rest of the paper is organized as follows: Section 2 reviews the related work on Smart Manufacturing Systems. In Section 3, we present the development framework with the three phases, Smart Manufacturing System Integration model, Simulation-based Evaluation, and the Final Model. Section 4 concludes the paper.

II. Related Work

Today, the market is driven by consumers' expectations in terms of better quality, lower cost, and less lead-time. The efficiency of traditional manufacturing system is not sufficient to meet customers' expectations [26]. According to Shen and Norrie [41], the conventional manufacturing operations are inefficient to fulfill the rapid changes in the market requirements. Finding better ways by manufacturers become a vital need to satisfy the market [42]. Therefore, to bridge the gap between expectations of consumers and actual productions, adoption of innovative and non-traditional processes is crucial.

Fig. 1 shows the evolution of the manufacturing system, which can be traced back to the middle of the 18th century during the industrial revolution with a steam-engine. As time progressed, during the age of electricity, the mass production system was introduced in the 19th century. The third of the Industrial Revolution happened in the 20th century, where computers and automation (flexible manufacturing system) are introduced. Finally, the forth industrial revolution or the era of Industry 4.0 is introduced and is called Smart Manufacturing System [43]. In SMS, human operations are replaced by robotics equipped with necessary algorithms and marked by a fusion of technologies.

The aim of the Smart Manufacturing System (SMS) is to share the right data to the right machine at the right time with required format [26]. Several terms are used in the literature for SMS such as an intelligent factory, a smart factory, factory of things [44]. In 2011, Germany introduced the terms of industry 4.0, which is referring to SMS. They provided a vision that emphasized on using communication technologies based on Cyber Physical System (CPS), Internet-of-Things (IoT) and IoS (Internet of Services) to resolve SMS obstacles [43].

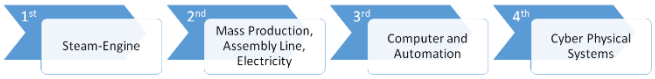

Fig. 1. Evolution of Manufacturing Systems

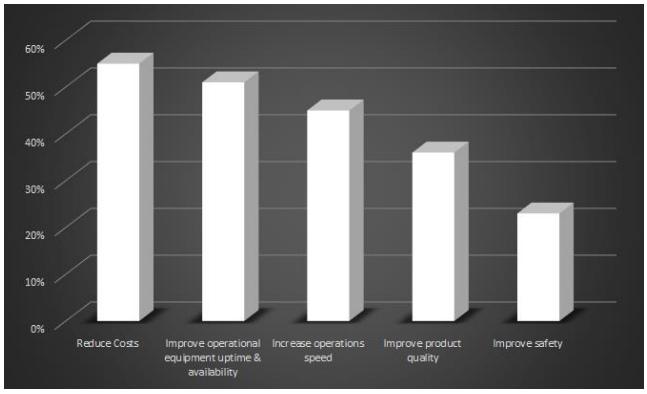

Fig. 2. Smart Manufacturing Benefits.

According to NIST [35] SMS is a "fully-integrated, collaborative manufacturing systems that respond in real time to meet changing demands and conditions in the factory, in the supply network, and in customer needs". Rockwell Automation defines SMS as "Smart Manufacturing is a highly connected, knowledge-enabled industrial enterprise where all business and operating actions are optimized to achieve substantially enhanced productivity, sustainability and economic performance".

A study made by Coalition (2011) reported the impact of SMS over a 10 years' time. Among the impacts, reduces safety incidents by 25%, improving energy efficiency by 25%, improves operating efficiency by 10%, minimizes cycle times by 40%, improves the lead-time by 10 times faster and increases revenue by 25%. Fig. 2 shows the result that reveals the benefits of SMS as reported by Aberdeen [27],

SMS receives increasing attention in Malaysia in a seminar entitled "Government's Role in Industry 4.0" organized by the Ministry of International Trade and Industry (MITI) [28]. Six issues have been highlighted to enable the implementation of SMS in Malaysia, one of them is the lack of standards and technology. A task force has been formed to come up with a proposal that would mitigate these issues.

According to SME Corp Malaysia [29], smart manufacturing has multiple impacts as efficiency, productivity, return of investment, technology convergence, mega trends. To advance SMS, leading countries such as United States and Germany are focusing on related key technologies such as [3], [5]-[17]:

- Internet of Things (IoT) to collect real-time data and exchange it with other resources at real-time.
- Cyber-Physical Systems (CPS) to monitor or control a physical process via internet in a safe, reliable, efficient and real-time way using embedded computer and networks.
- Big data to process large and complex datasets using special algorithms.

- Cloud computing to enable a full sharing and circulating of manufacturing resources.
- Sensor to share, exchange, and control data.
- Smart energy to monitor, analyse and optimise the consumption of the energy.

Meanwhile, SME Corp Malaysia [29] proposes nine pillars as key technologies to implement SMS as shown in Fig. 3.

However, focusing on the key technologies only would not mitigate the difficulties because few studies have discussed the configuration challenges prior to implementation while establishing new SMS [18]-[20]. Configuration involves identifying required machines, their quantities, and the workflow between machines, as well as the required technologies [19]. In addition, an evaluation for a selected configuration needs to be conducted prior to implementation too. The selection of a particular configuration and evaluation of the system prior to implementation mainly requires modeling and simulation study [21]-[23].

Wang et al. [30] propose a framework based cloud-integrated manufacturing to develop a self-organized smart factory. The framework incorporates wireless networks, cloud, big data analytics, and terminals such as machines, products, and conveyors to create intelligent automation production. Giret et al. [31] propose an approach for assisting service-oriented Intelligent Manufacturing Systems (IMSs), which combine multi-agent with service-oriented architectures [64]. Li et al. [32] discuss the possible AI applications needed to develop IMS in China. Giret et al. [33] proposes a framework that assist the establishment of IMS by identifying the manufacturing components. Lee et al. [34] presents a cyber-physical system (CPS) architecture to provides practical guideline for the future SMS. Recent research by Nagadi et al. [19] propose a configuration framework using computer-based tools such as business process modelling and notation tool, agent-based modelling tool, expert systems, and discrete event simulation tool.

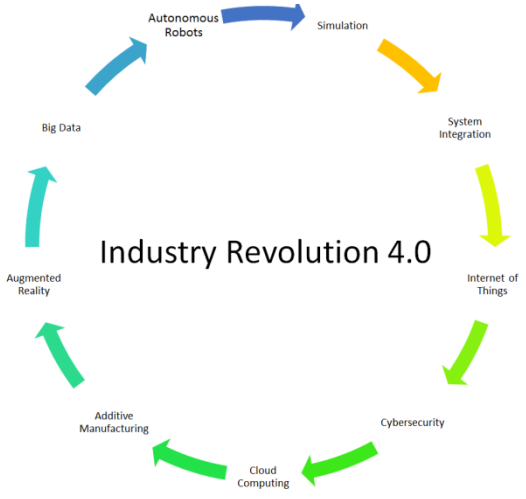

Fig. 3. Nine Pillars Proposed by SME Corp Malaysia.

However, very limited studies have been conducted on investigating and formulating the configuration factors, which can assist the industries' senior management in planning and establishing new SMS that minimize the operational cost and time, as well as improving efficient machine's utilization. To fill this gap, this study proposes to formulate a framework that generates SMS configurations. The proposed framework aids decision-makers in designing better SMS configurations and capabilities.

The proposed framework that is based on an application development that engages engineers throughout in a three-phased, iterative process of application modelling; evaluation to ensure optimal configuration and adoption; and finally implementation.

As shown in Fig. 4, the modelling phase consists of Manufacturing System Components which are System Configuration; Functional Model; and Industrial Processes, and Smart Components which are Internet of Things (IoT); Cloud Computing; Big Data; Cyber-Physical System (CPS); and Agent-based Modelling (ABM). The evaluation phase consists of Simulation Model that includes Computer-based Simulation and Discrete Event Simulation (DES); finally, the implementation of the Smart Manufacturing System.

A. Smart Manufacturing System Integration Model

The modelling phase consists of two components, hardware and software. The hardware is represented by the manufacturing system components, while the software components are represented by the smart components. The combination of both constitutes the proposed Smart Manufacturing System Integration Model.

The manufacturing system components are System Configuration, Functional Model, and Industrial process. The System configuration specifies the type and numbers of required machines. The Functional Model presents the behavioral processes of a machine according to its functions while the industrial process determines the required interaction model among machines that reflects the production process flow.

The smart Components are Internet of Things (IoT) to establish communication between these machines/Agents; Cloud computing to enable a full sharing and circulating of manufacturing resources; Big Data to process large and complex datasets using special algorithms; Cyber-Physical System (CPS) to monitor or control the physical process via IoT and embedded algorithms. Agent-based Model (ABM) to model the behavior of the identified machines.

As shown in Fig. 5, the model firsts determines the configurations of the required system, then model the behavior of each component using ABM concept, and finally run and control the process via IoT, Cloud Computing, Big data, and CPS. The combination between the Manufacturing System Components and The Smart Components via agent-based Modeling constitutes the Smart Manufacturing System Integration model.

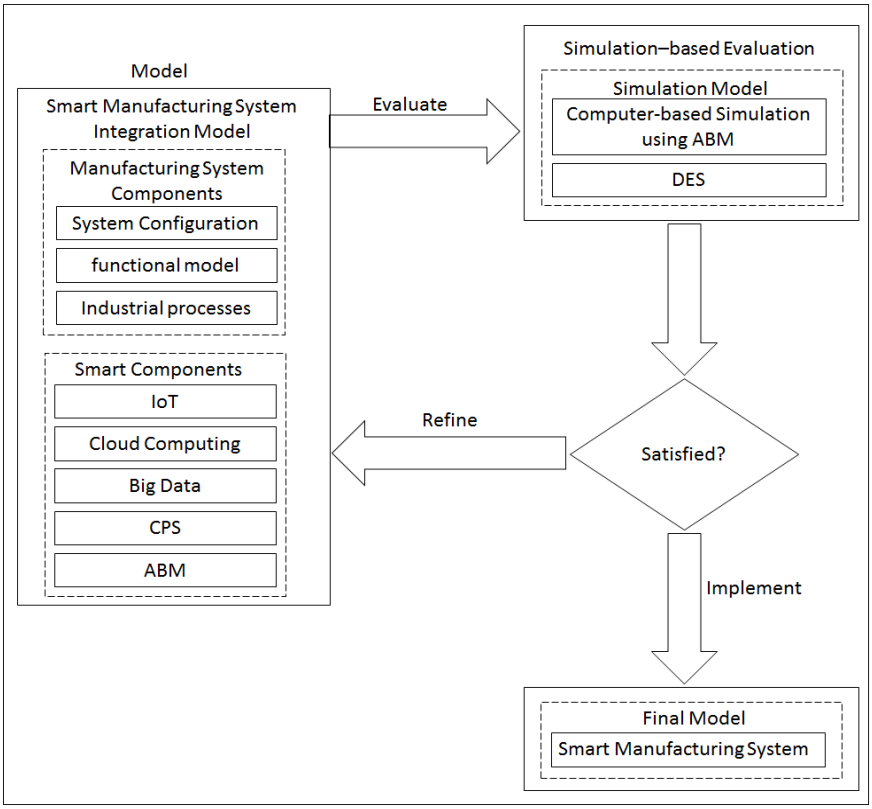

Fig. 4. Smart Manufacturing System Development Framework.

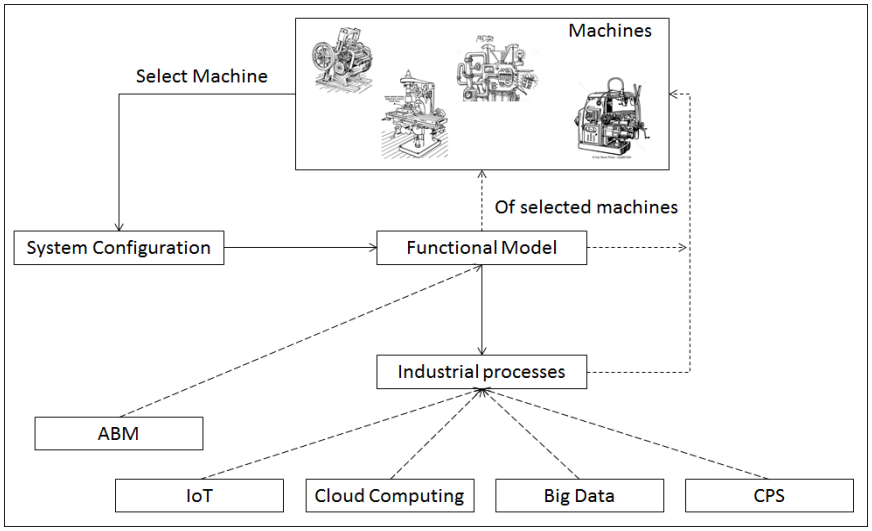

Fig. 5. Smart Manufacturing System Integration Model.

B. Simulation-based Evaluation

To simulate the system prior the implementation, two approached can be utilized for this purpose [19], Agent-based Modeling (ABM) to imitate a machine behavior and Discrete Event Simulation (DES) to mimic the industrial process flow as shown in Fig. 6.

The complete simulation strategy to evaluate a proposed system prior implementation is shown in Fig. 7. First software architects collaborate with manufacturing engineers to design the primary model. The manufacturing engineers specify the required type and number of machines and they describe the production process flow, in other words, the communication architecture between machines. Subsequently, software architects study the function and behavior of each machine to model its agent accordingly. Once all agents are modeled to represent the specified machines, software architects design the DES to mimic the described production process flow by the manufacturing engineers. The next step is evaluating the primary model via the simulation.

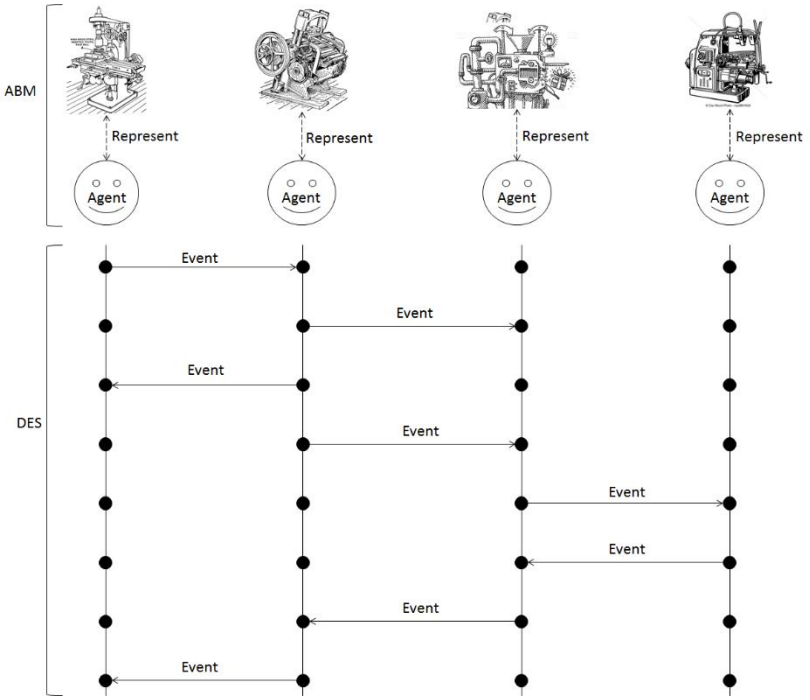

Fig. 6. Simulation Components.

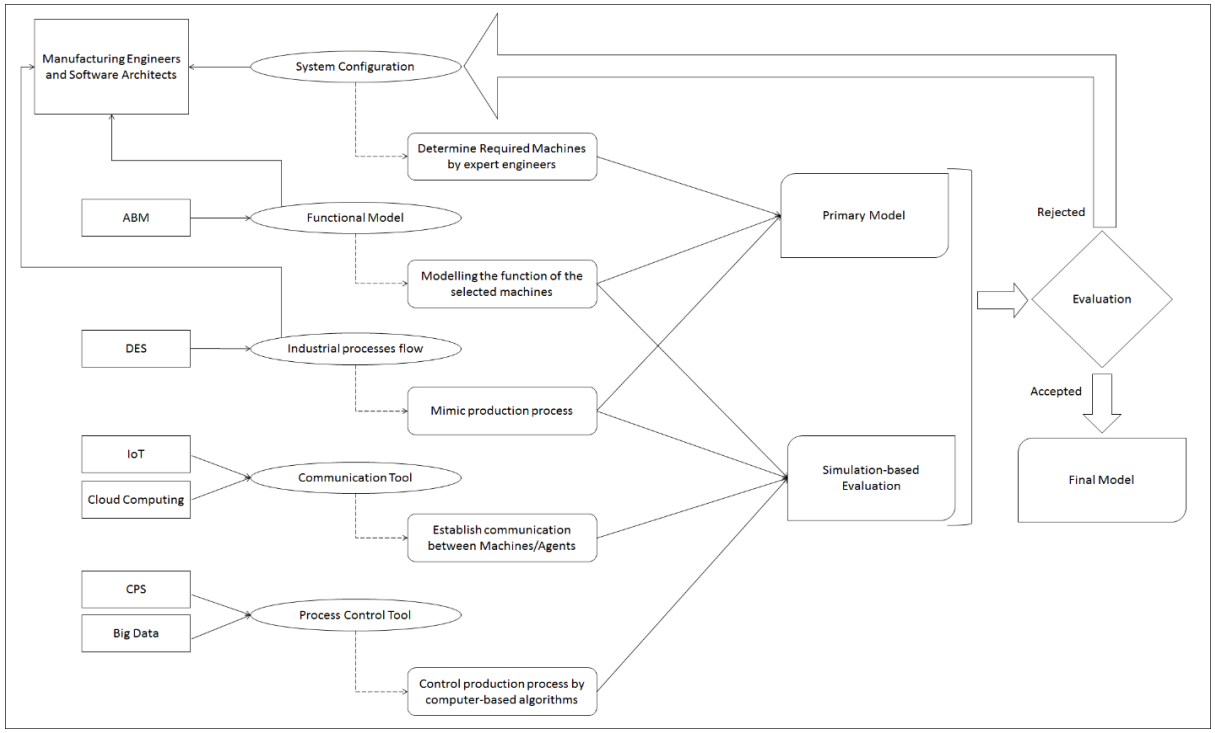

Fig. 7. Simulation-based Evaluation Model.

As shown in Fig. 4, the simulation components are ABM, DES, IoT, Cloud Computing, CPS, and Big Data. As mentioned earlier, ABM imitates machines functions and behavior and DES simulates production process flow. IoT and cloud computing provide a communication tools, IoT can provide agent to agent, or agent to cloud-cloud to agent. CPS is used to control the physical process via algorithms and network while the big data provide an effective mean to handle massive data accumulated overtime.

C. Final Model

The final model can be obtained after evaluating and subsequently refining the primary model. Several factors can be measured to evaluate the primary model such as applicability, efficiency, reliability, implementation cost,

effectiveness, etc. If one or more factors are not within expectation, system re-configuration can be made by engineers and simulation-based evaluation can be applied again until all evaluation factors are in acceptable level.

III. Conclusion

The study of development framework in establishing new SMS is crucial for pre-implementation assessment that leads to minimized operational cost and time, as well as efficient machine's utilization. Thus, in this paper, we develop a framework that is based on an application development methodology that engages engineers throughout in a three-phased, iterative process of application modelling; evaluation to ensure optimal configuration and adoption; and finally implementation. The modelling phase consists of Manufacturing System Components which are System Configuration; Functional Model; and Industrial Processes, and Smart Components which are Internet of Things (IoT); Cloud Computing; Big Data; Cyber-Physical System (CPS); and Agent-based Modelling (ABM). The evaluation phase consists of Simulation Model that includes Computer-based Simulation and Discrete Event Simulation (DES); finally, the implementation of the Smart Manufacturing System.

In our future work, we shall implement the developed framework to evaluate the primary model on different scenarios and subsequently produce the final model to ensure the quality, lead-time, and cost that optimize the usage of the capital investment and satisfy customers' requirements.

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Smart City Parking Lot Occupancy Solution

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***Abstract*—In the context of Smart City projects, the management of parking lots is one of the main concerns of local administrations and of industrial solution providers. In this respect, we have presented an image processing application, which overcomes the issues of classical electro-mechanical solutions and employs the feed of a surveillance camera. The final web-based interface could provide to the clients the real-time availability and position of the parking space. The proposed method uses a series of feature measures in order to speed-up and accurately classifies the occupancy of the space. Using a published benchmark, our method has proved to provide very accurate results and have been extensively tested on two proprietary parking locations.**

***Keywords*—Smart city; car parking; occupancy; monitoring system; image features**

I. Introduction

A large number of the parking lot systems use counters on entry and exit barriers, but unfortunately, erroneous results are obtained if a vehicle occupies more than one parking space or when the parking lot includes several types of parking spaces. A solution to the problem was to add magnetic sensors on each parking space, however, in practice; this type of system involves very high costs.

Therefore, the scope of our research was the development of a computer vision system for the detection of parking spaces. The motivation behind it resides in the fact that, a video camera installed in the car park for security reasons can also monitor the parking spaces. Implementing this smart parking system has many benefits: it is helpful to customer drivers, low cost, can be used in everyday life, decreases the time needed to search for a parking space as the driver can steer quickly to the available parking spaces, eliminates redundant traffic generated by the search for available spaces, can be installed quickly and easily, and it is easier to maintain than current systems.

However, the main challenges of the camera-based systems are the lighting conditions: low light or temporal and spatial lighting fluctuations, shadows and reflections from the surface of other vehicles.

In this respect, the method proposed in paper [1], employs geometric modelling and parking areas layouts as means to automatically extract the parking lot configuration. The extraction of the parking spaces is based on white or yellow lines, using high-resolution aerial images, indicating that a large number of parking spaces can be accurately. Thus, after defining the geometric and layout models, a method of parking space extraction is proposed, using both parking space and vehicle detection. Once the objects detection has been performed, by comparing against the model, a grouping function is applied to the relative positions, according to the rules of the geometric.

In the paper of Gálvez del Postigo et al. [2], after initialization, a background extraction was performed and a map was created. Using this map, the vehicles are detected and tracked in order to determine their status. The first step of consists of defining the parking areas to be analyzed, from which a binary mask will be created. Thus, a background model is needed in order to detect moving vehicles. For this purpose, the chosen approach involves the implementation of Mixture of Gaussians techniques. The Transition Map is a technique that works well for detecting parked vehicles. In order to determine the status of the parking spaces, two instances are analyzed: parked vehicles and moving vehicles.

In Števanák et al., the issue of the parking space occupancy is addressed using an open source solution called PKSpace [3]. It uses a vision-based approach, employing an automated learning model, in order to categorize the images of the parking spaces as either occupied or vacant. It also allows the user to choose either a default model, that is part of the solution proposed, or to create their own data set for a particular parking lot and to develop the model based on this information. At the same time, this solution offers application programming interfaces (APIs) which allow external systems to process the data collected and store it for later use.

In paper [4], the authors have studied the performance of image processing algorithms when the multithreading approach is applied on different platforms (single core / multi-core). Results shown that multithreading improve processing time on single-core or multi-core platforms. With a single core, the best results are achieved when using a combination of small size images and less complex algorithms, while the combination of a smaller size image and more complex algorithms improves performance when working with multi-core processors. Multithreading programming can improve the performance of the multi-core processor when complex image processing algorithms are applied.

Vítek et al. shown that detecting parking spaces occupancy is constantly on the rise, especially in big cities [5]. The paper uses wireless cameras to manage parking spaces and determines the parking space occupancy based on the camera feeds. The proposed system employs small camera modules based on Raspberry Pi Zero and an efficient algorithm for occupancy detection based on the Histogram of Oriented Gradients (HOG) and Support Vector Machine (SVM) classifier. The basic features include information concerning the vehicle's orientation, where it can be more accurately determined. The solution presented can provide occupancy information at a rate of 10 parking spaces per second with an accuracy of more than 90% in various weather conditions.

The scope of this paper was to propose a solution that can extract the parking spaces and detect the occupancy of the parking lot, using a sequence of images acquired from video cameras. Therefore we have combined techniques that are capturing and detecting the presence of vehicles on parking spaces using image processing, parking spaces detection based on markings, detection of the parking lot occupancy, identification of available and occupied parking spaces, outlining parking spaces, counting the number of available and occupied parking spaces. The proposed method allows sending information about the occupancy of the parking lot to customers using HTTP requests.

II. Proposed System

Most studies in this field have a sequential approach; and therefore, a lot of time required for processing. Thus, we have proposed a method in which the sequencing is done by parallel segmentation, each image is divided into several parts and then one thread controls each one of them. After segmentation, all parts are merged and the desired result is obtained [4].

The processing steps of the method are the following:

a) Parking lot map description;
b) Image frame acquisition and pre-processing;
c) Adaptive background modelling;
d) Computation of features;
e) History calculation;
f) Fusion of results for each parking space;
g) Defining parking space status;
h) Feeding data to Client-Server system;

The general structure of the proposed system is presented in Fig.1.

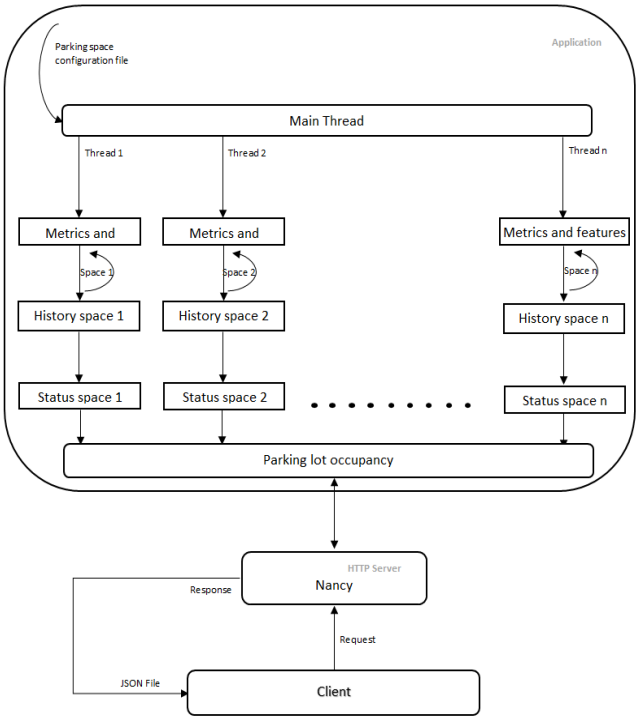


Fig. 1. System Block Diagram.

A. Parking Lot Map

In an offline configuration stage, using a template image taken from each camera, the following data are defined: the coordinates of each parking space, the number of parking spaces, as well as the centroid/midpoint of each parking space. This information is saved in a configuration file, uploaded one time, at system initialization. The coordinates of the parking space, as well as the midpoint, are converted from screen coordinates into Cartesian coordinates.

Sample file:

```
Number:1;Points:-626 -24,-541 4,-496 -92,-594 -116;
Centroid:-563 -58
Number:2;Points:-471 12,-415 32,-367 -44,-428 -66;
Centroid:-420 -17
Number:3;Points:-336 52,-290 65,-240 -6,-292 -17;
Centroid:-289 23
Number:4;Points:-234 84,-177 102,-117 35,-184 19;
Centroid:-177 59
```

The original image is further divided into several regions, aiming to simplify the image representation into a more relevant and easier way to be analyzed. This process is used to locate each parking space and its limits, based on the four coordinates from the configuration file. A perspective transformation is also applied for each parking space and a new region is obtained from the resulting transformation matrix. During this process, a label is assigned to each parking space. In consequence, the template image is divided into several regions and a thread will process each one of them, in order to determine its status.

B. Multithreading Programming

In the multithreading approach, the shared memory in which the threads work is the image pixel matrix. The work load and the part of the matrix that each thread has to handle are determined by the main thread [6]. A multithread process has several simultaneous execution points [7]. Using multiple threads allows an application to allocate long-term tasks, so that they can be performed concurrently. This is also possible due to the significant improvements in the multi-core systems.

Nowadays multi-core processors are widely deployed in both server and desktop systems. The performance of multithreaded applications can be improved when using multi-core systems, since the thread charge can be moved to the core, which works with several threads simultaneously [8]. A good example of applications that benefit from multithreading is Computer Vision ones [9]. The main idea behind parallel processing of images is to divide the problem into simple tasks and solve them simultaneously so that the total processing time is the sum of the finished tasks (best case scenario) [10]. Image processing can be a time consuming task based on the image matrix structure that drives this process towards a multithreading algorithm.

The proposed solution uses execution threads to improve application performance. After identifying the number of parking spaces, one thread is created to process each parking space, using Thread Pooling. These are pre-fabricated threads that can be launched more quickly by the OS. We cannot define a name for a thread in the thread pool. The threads in the thread pool only work in the background. The execution

threads are created using the Task Parallel Library (TPL). TPL offers a basic form of structured parallelism and is based on the concept of task.

For each parking space, the image processing involves the analysis of the features (Histogram of Oriented Gradients-HOG, Scale Invariant Feature Transform–SIFT corner detector, color spaces - YUV, HSV and YCbCr).

HOG is a feature descriptor used to detect objects by counting the occurrences of gradient orientation in areas of interest. SIFT is a descriptor used to detect the number of the points of interest (corners).

The HSV color space has 3 channels: the Hue, the Saturation and the Value, or intensity. The Hue channel represents the "color". The saturation channel is the "amount" of color (this differentiates between a pale green and pure green), and intensity is the brightness of the color (light green or dark green). YUV defines a color space in terms of one luminance (Y) and two chrominance (UV) components. YCbCr color model contains Y, the luminance component and Cb and Cr are the blue-difference and red difference Chroma components.

The standard deviation values for the three channels V (`devSYUV`), S (`devSHSV`), Cb (`devSYCrCb`) of the color spaces YUV, HSV, YcbCr, the number of corners (`noSIFT`), and the HOG descriptor mean (`meanHOG`) were used to create a history, based on predefined thresholds: 0.03 for mean HOG, 7 for number of corners resulting from SIFT, 1.4 for V component from YUV, 9 for S component from HSV and 1.1 for Cb component from YCbCr This history tracks the availability of parking spaces.

Each value from metrics and measurements compares with a default threshold. Based on this comparison, counted the values of 1 (`statusOccupied`) and 0 (`statusAvailable`), and the status is determined by the predominant value. If predominant is 1, the parking space is occupied, otherwise, is free.

```
Function SetStatus (indexParkingLot)
    if    meanHOG[indexParkingLot]    >    0.03    then
statusOccupied++;
    else statusAvailable++;
    end if
    if     noSIFT[indexParkingLot]     >=     7     then
statusOccupied++;
    else statusAvailable++;
    end if
    if    devSYUV[indexParkingLot]    >    1.4    then
statusOccupied++;
    else statusAvailable++;
    end if
    if    (devSHSV[indexParkingLot]    >    9)    then
statusOccupied++;
    else statusAvailable++;
    end if
    if   (devSYCrCb[indexParkingLot]   >   1.1)   then
statusOccupied++;
    else statusAvailable++;
    end if
    if   (statusAvailable   >   statusAvailable)   then
status = 0
    else status = 1
    end if
EndStatus
```

For more accurate results, was created a history of 20 frames that contains the status of each parking space, obtained from measured metric and measurement results. With each new frame, it is tested if the number of frames originally set has reached. If yes, then adding the status to the list produces the effect of "Sliding Window", which requires the elimination of the first value of the buffer and the addition of the new value in the list, according to the FIFO principle. Thus, this technique allows for the last changes to each parking space to be retained in order to determine the status. Over time, this process helps stabilize changes in the background, such as the gradual change from day to night, different weather conditions.

```
for parkingSpace=0:totalNumberParkingLot
   if(sizeOfBuffer < 20)
        Status = SetStatus(parkingSpace)
        Add status in buffer
   else
        SlidingWindow
        Status = SetStatus(parkingSpace)
        Add status in buffer
   end if
   if predominat is 1 in buffer StatusParkingSpace=1
   else StatusParkingSpace = 0
   end if
end for
```

The information concerning the parking lot occupancy emerges once each frame is processed, thus identifying the number of available spaces, as well as occupied ones, out of the total number of parking spaces considered.

C. Client Interface

There are many alternatives to creating a web server for the purpose of client access to parking lot occupancy. Within this system we have used HTTP server based on Nancy, which is a framework for building HTTP-based services in .NET. With these HTTP-based services, this framework can handle all standard HTTP methods such as GET, POST, PUT, DELETE, HEAD etc. Everything in Nancy is "HOST's". A host acts as a framework or adapter for a hosting environment, and allows Nancy to run on existing technologies such as ASP.NET, WCF and so on.

The application must be downloaded and installed using the NuGet package manager, as it will download the complete references to the current solution or project. Once Nancy is installed, the first module can be created. The requests are handled by the modules. The Nancy website regards a module as "the place where you define the behavior of your application". Like Controllers in MVC, there are modules in Nancy. A single module must be defined for a Nancy app, which becomes the starting point of an application. We can create as many legacy modules from NancyModule as we need. In the class builder, the routes are defined with Get ["/"]. A route must follow the same pattern as Literal Segments, Capture Segments (`{yourname}`), and regular expressions.

The system listens to one or more addresses in order to send the necessary information to an http request. The system can listen to multiple addresses by creating a URI array and assigning it to the constructor for NancyHost. The result is that you can listen on multiple network interfaces. This is useful for example, in situations where you have a server that has to listen on two different interfaces, and respond differently to both.

With Nancy HTTP, you can tell which request came from which IP, allowing you to selectively say in program code which connection is allowed access to which functionality.

The life cycle of each Nancy application starts with receiving the HTTP request and ends when it sends the HTTP response back to the client. Any good web framework allows you to send data to it. Nancy is very flexible in terms of answering. To prepare more complex answers with headers for the information to be sent, a new Response object is built. The response is a JSON and it looks as follows:

```
{
        "Parking_lot_1":
        {
          "TotalParkingSpaces":20,
          "FreeParkingSpaces":12,
          "OccupiedParkingSpaces":8
         },
        "Parking_lot_2":
        {
          "TotalParkingSpaces":38,
          "FreeParkingSpaces":15,
          "OccupiedParkingSpaces":23
        }
}
```

The data sent in JSON format includes the names of the installed cameras, and for each one the following information is provided: the total number of parking spaces, the number of vacant spaces and the number of occupied spaces.

Example of HTTP request: http://localhost:5000/data

III. Results

In the purpose of evaluation, three metrics were computed: accuracy, sensitivity and specificity defined in equations 1, 2 and 3. In these equations, TP (True Positive) is the number of occupied spaces classified as occupied, TN (True Negative) is the number of vacant spaces classified as vacant, FP (False Positive) is the number of vacant spaces classified as occupied and FN (False Negative) is the number of occupied spaces classified as vacant [11].

$$\text{Accuracy} = (TP + TN)/(FP + FN + TP + TN) \quad (1)$$

$$\text{Sensitivity} = TP/(TP + FN) \quad (2)$$

$$\text{Specificity} = TN/(TN + FP) \quad (3)$$

where TP (True Positive) is the number of occupied spaces classified as occupied, TN (True Negative) is the number of vacant spaces classified as vacant, FP (False Positive) is the number of vacant spaces classified as occupied and FN (False Negative) is the number of occupied spaces classified as vacant [11].

Table 1 shows the accuracy resulted from testing our system under various weather conditions: overcast, rainy and sunny days in comparison to the CNRPark+EXT results [12]. We have employed the same parking lot map as in the benchmark provided in CNRPark. For the first benchmark, 8 parking spaces were selected, and for the second benchmark, 26. It can be seen that the results were encouraging, with a minimum accuracy rate of over 90%.

The accuracy, sensitivity, and specificity are calculated in various weather conditions, with results ranging between 91%-99%. The best accuracy is in overcast conditions for both benchmarks, as seen in Fig. 3 and 5. In Fig. 2 and 4, the incorrect and correct detections can be observed on a number of frames from the two benchmarks.

A. Specific Benchmarks Results Examples

1) Overcast weather: The results on an overcast day for the two benchmarks are over 98% accurate, which translates into very good detection accuracy. Figure 6 shows screenshots of the two examples used.

2) Rainy weather: The screenshots in Figure 7 were taken on a rainy day for various benchmarks. The accuracy under these weather conditions is over 90%. It shows that the problems persist in the case of camouflage.

3) Sunny weather: The screenshots in Figure 8 were taken on a sunny day for various benchmarks. The accuracy under these weather conditions is over 91%. It shows that the problems persist in the case of camouflage and shade.

TABLE I. Results Comparison on Different Benchmarks

Results	Accuracy		
	Overcast%	**Rainy%**	**Sunny%**
Benchmark 1 with proposed method	99.708	90.088	91.566
Benchmark 1 from [12]	100	100	99.900
Benchmark 2 with proposed method	98.313	95.070	91.564
Benchmark 2 from [12]	100	100	100

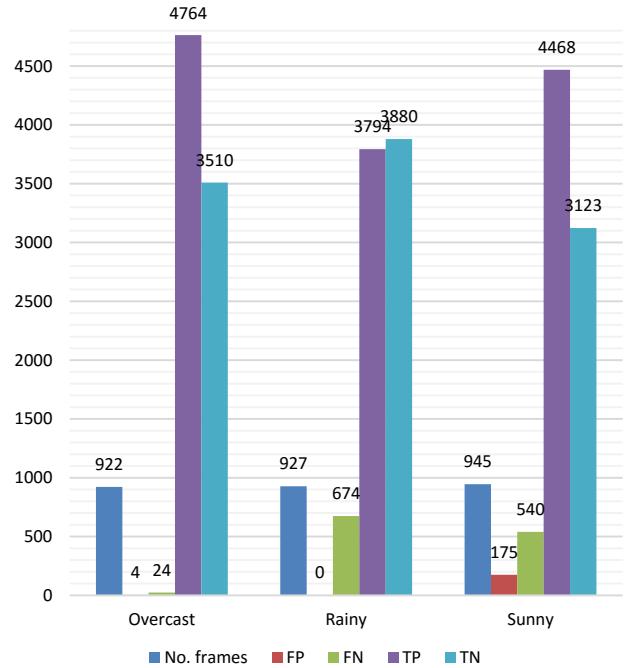


Fig. 2. The Benchmark 1 Classification Results under different Weather Conditions.

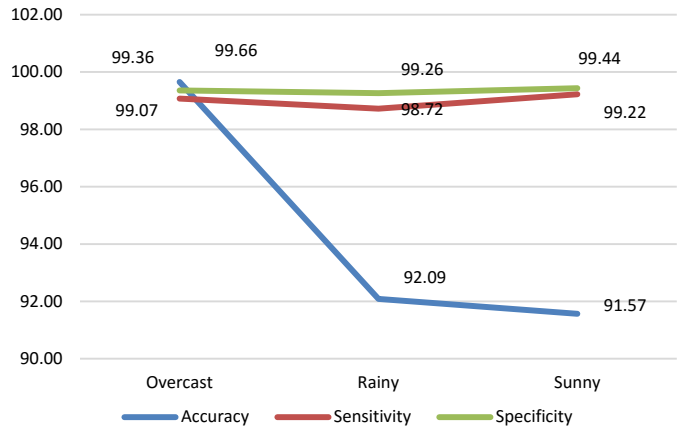


Fig. 3. The Benchmark 1 Results of Three Measures on different Weather Conditions.

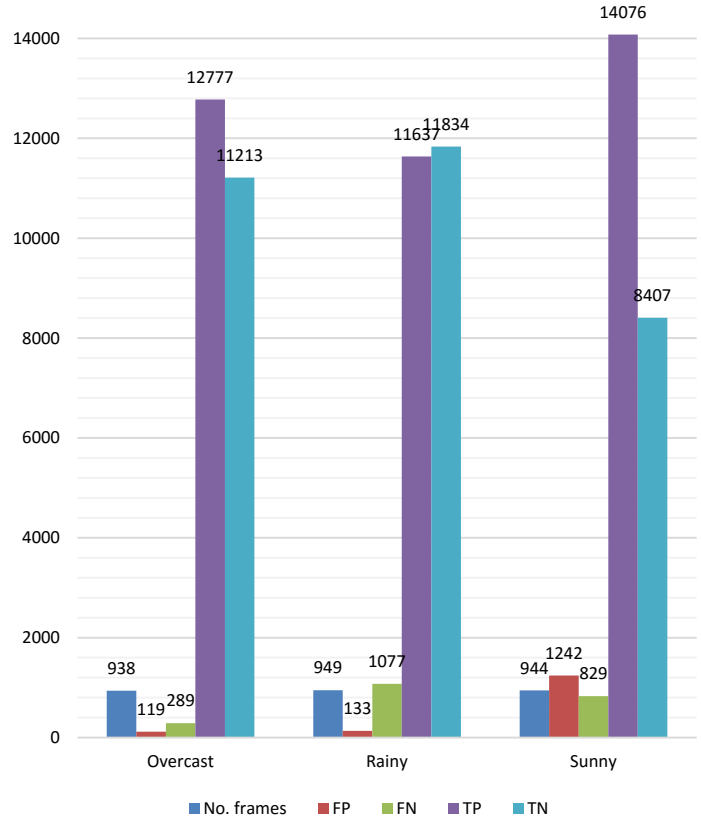


Fig. 4. The Benchmark 2 Classification Results under different Weather Conditions.

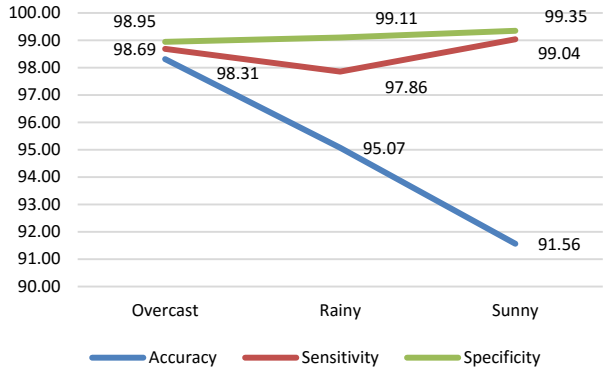
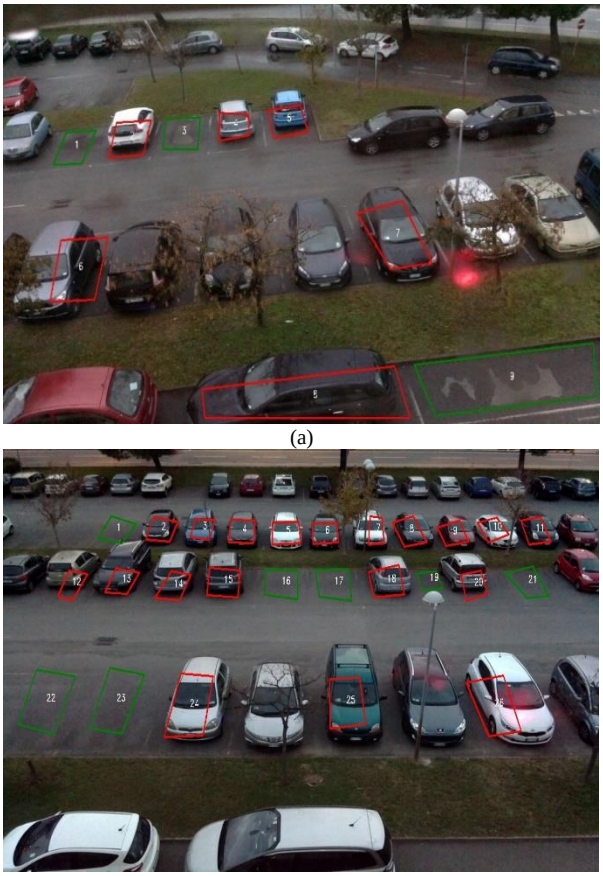


Fig. 5. The Benchmark 2 Results of Three Measures on different Weather Conditions.



(a)

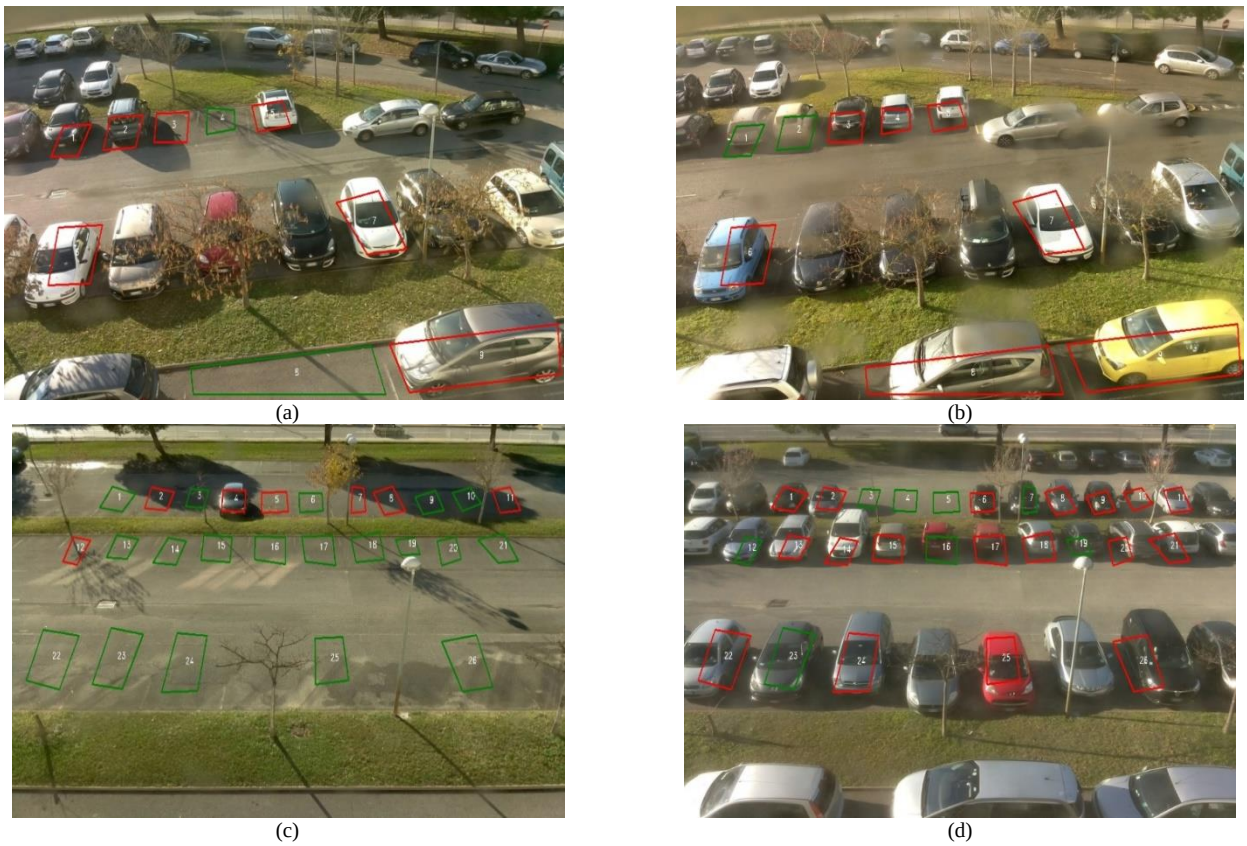
(b)

Fig. 6. Results on an Overcast Day for (a) Benchmark 1; (b) Benchmark 2.

(a) (b)

(c)

Fig. 7. Results on a Rainy Day for (a) and (b) Benchmark 1 (c) Benchmark 2.



(a) (b)

(c) (d)

Fig. 8. Results on a Sunny Day for (a) and (b) Benchmark 1; (c) and (d) Benchmark 2.

IV. Conclusions

In this paper, we have presented a solution for the detection of parking spaces using image sequences acquired from video cameras. A technique based on computer vision algorithms have been investigated, together with a parallel implementation and the facility to provide to clients the information about the availability of a parking lot using HTTP. Based on two available benchmarks, the results obtained achieved minimum accuracy rate of over 90%. The unsolved system problems remain the presence of shadows and camouflage. Shadows are recognized as objects, in this case a vehicles, and thus, a partially shaded vacant space is detected as occupied.

Acknowledgements

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FLACC: Fuzzy Logic Approach for Congestion Control

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***Abstract*—The popularity of network applications has increased the number of packets travelling within the routers in networks. The movement expends most resources in such networks and consequently leads to congestion, which worsens the performance measures of networks, such as delay, packet loss and bandwidth. This study proposes a new method called Fuzzy Logic Approach for Congestion Control (FLACC), which uses fuzzy logic to decrease delay and packet loss. This method also improves network performance. In addition, FLACC employs average queue length (aql) and packet loss (PL) as input linguistic variables to control the congestion at early stages. In this study, the proposed and compared methods were simulated and evaluated. Results reveal that fuzzy logic Gentle Random Early Detection (FLGRED) showed better performance results than Gentle Random Early Detection (GRED) and GRED Fuzzy Logic in delay and packet loss and when the router buffer was in heavy congestion.**

Keywords—Congestion; Network Result Performance; GREDFL

I. INTRODUCTION

Computer networks are utilised in organizations, homes and offices. This situation motivates the movement of huge data within computer networks around the world [1-3]. The data are transferred in the form of small pieces called packets. The generated packets form current application data that are temporarily stored during their transfer in routers and switch to network resources. Every router resource has a buffer to queue and stores the packets before transferring to their destination. However, when the available space resources of the network router buffer are not all occupied and thus leave enough space for new packets, incoming packets can drop directly [4, 5]. This situation causes congestion, which happens when arriving packets at router surpass the existing resources [6, 7]. One of the oldest methods that manage and control congestion is tail-drop, which works in the router buffer [8, 9]. The tail-drop method uses first-in-first-out (FIFO) module and manages the congestion at the buffer when the buffer reaches the limit. When incoming packets arrive at the buffer at little amounts, the tail-drop method effectively operates with good performance. However, the method fails when high traffic exists, as the router buffer quickly overflows and every arriving packet can be dropped [10]. Fig. 1 illustrates the tail-drop method buffer.

Generally, the disadvantages of existing congestion control algorithms can be summarized as follows. Existing algorithms use static probability for packet dropping, and several propose an addition target value that leads to a large number of packet drops when the probability value is high and bursting traffic is present. However, the parameterization problem still exists in most dynamic methods. Bursting traffic causes a heavy congestion signal, which then leads to significant packet drops. Conversely, network performance becomes degraded when the probability of packet dropping is set too low. Specifically, Dp, PL, mql, and D increases, and T decreases. Consequently, a dynamic mechanism is required to implement packet dropping based on the congestion status. This paper proposes an enhance method, Stabilized Dynamic GRED (SDGRED), to address the aforementioned disadvantages and to improve network. When the high traffic arrive at the router buffer (Bursty Traffic) causes many limitation and problem [11]. Such as; 1) increase the queuing time delay because the packet spends a lot of time inside the router buffer; 2) Increase the packet loss especially when the heavy congestion is present; 3) Overwhelmed the link bandwidth because retransmitting the packet has been dropped from the router buffer.

Unfortunately, the tai-drop method failed to control the congestion at the buffer. Therefore, many Active Queue Management Method (AQM) have been proposed to detect and eliminate the bursty traffic problem that exists in previous method [1, 12, 13]. In addition, the main goal of the AQM methods discover and manage the congestion at early before the router buffer reaches to the limit size. On the other hand, AQM methods employed dropping probability DP to control the congestion at the buffer by dropping the packets earlier overflow. Consequently, the AQM methods decrease the packet loss and queuing delay by random dropping strategy. Many researchers have been developed and enhanced the AQM methods. Such as, random early detection (RED) [14], GRED [15], Adaptive GRED [16], Dynamic GRED [10], and ENAGRED [17]. Many AQM methods using fuzzy logic, such as GREDFL [18], FLRED, Enhanced Random Early Detection using Responsive Congestion Indicators [19] and REDFL [20]. Though, the current AQM methods cannot predict the congestion at early stage in effective manner, as a result decrease performance of the network [21, 22]. Current paper a new method proposed, to discover the congestion earlier to detect the problems that appear in trail-drop method and enhance the network performance. Especially, delay and packet loss performance measures. In addition, solve the problem of parameterization AQM methods. The proposed method uses the fuzzy logic to utilizing the router buffer by using (aql) and (PL).

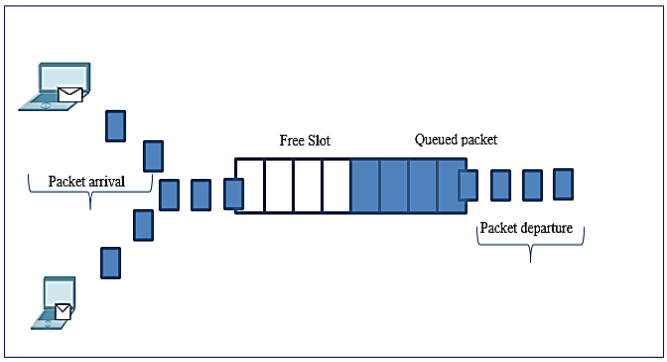

Fig. 1. Tail-Drop Router Buffer.

The current paper is planned as the following. Section 2 shows the literature review work regard to AQM method. Section 3 explains the FLACC method and stages of implementation. Section 4 displays the simulation environment and the parameter that used in the proposed method. Section 5 discuss the performance result of the proposed and compared method. Section 6 includes the conclusion of the current paper. High traffic at the router buffer (Bursty traffic) results in problems, such as 1) increased queuing time delay because packets spend time inside the router buffer; 2) increased packet loss, especially during heavy congestion; and 3) overwhelmed link bandwidth because retransmitting packets has been dropped from the router buffer [11]. Unfortunately, the tail-drop method fails to control the congestion at the buffer. Therefore, Active Queue Management (AQM) methods have been proposed to detect and eliminate the bursty traffic problem that exists in the previous method [1, 12, 13]. The main goal of AQM methods is to discover and manage the congestion early or before the router buffer reaches the limit size. AQM methods employ dropping probability (DP) to manage the congestion at the buffer by dropping the packets early in the overflow. Consequently, AQM methods decrease the packet loss and queuing delay by using the random dropping strategy. Many researchers have developed and enhanced AQM methods, such as random early detection (RED) [14], GRED [15], Adaptive GRED [16], Dynamic GRED [10] and ENAGRED [17]. Many AQM methods use fuzzy logic, such as Gentle Random Early Detection Fuzzy Logic (GREDFL) [18], FLRED and REDFL [20]. The inability of current AQM methods to predict congestion at early stages effectively decreases network performance [21, 22]. Thus, this study proposes a new method to discover the congestion early, detect the problems that appear in the trail-drop method and enhance network performance. Delay and packet loss performance measures are employed. In addition, the proposed method can solve the parameterisation problem of AQM methods. The proposed method uses fuzzy logic in utilising the router buffer by using (aql) and (PL).

II. Related Work

Congestion is a main question in networks. Thus, several scientists have developed and enhanced methods related to congestion control. RED was proposed in 1993 [14]. This method is a mechanism that controls congestion at the quick stage in the buffer and solves and overcomes limitations of the tail-drop method (see Fig. 2).

RED method uses a dropping policy to manage the congestion and discover it before the router buffer becomes full. Subsequently, RED method has two thresholds (minthreshold and maxthreshold) defined at the router buffer and employs an aql calculated value. The packet is dropped according to the following rules. When the aql is less than the minthreshold, no packets are dropped. When the aql is between the minthreshold and maxthreshold, the packets start to drop in low probability. Finally, when the packets are greater than the maxthreshold, the dropping value becomes one and every packet that arrives may overflow [14]. Hence, RED method improves the performance result better than the tail-drop method and decreases the bursty traffic problem.

GRED is another AQM method [15] that enhances RED method, solves the parameterisation problem and decreases Bursty traffic [22, 23]. Unlike RED, GRED method uses three thresholds (minthreshold, maxthreshold and doublemaxthreshold) in different positions at the router buffer to control congestion by using two different dropping probabilities (see Fig. 3 for GRED router buffer).

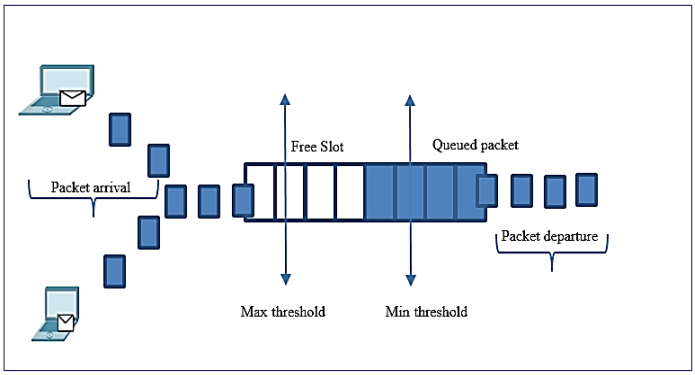

Fig. 2. RED Router Buffer.

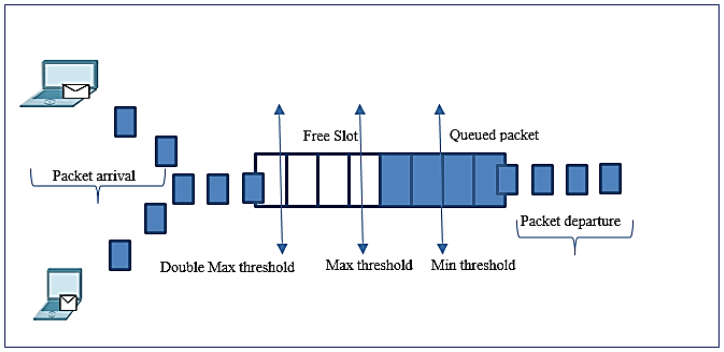

Fig. 3. GRED Router Buffer.

The dropping operates within the following rules. When the aql value is less than the minthreshold, no dropping occurs. If the aql value is between the minthreshold and maxthreshold, GRED method drops the packet according to the equation that is similar to the RED method [14]. When the aql value is between maxthreshold and double maxthreshold, GRED uses another dropping equation with high probability to prevent the router buffer from becoming full. Finally, when the aql is greater than the doublemaxthreshold, the dropping increases and reaches 1 as that of the RED method [15]. Subsequently, every packet that arrives at the router buffer overflows. The result reveals that GRED method outperforms RED, as the doublemaxthreshold has been added. DGRED method is proposed in [10]. Similar to GRED method, DGRED has the same number of thresholds. Unlike GRED method, DGRED employs adaptive threshold positions to enhance the performance and keeps the aql value at the level between minthreshold and maxthreshold by using target aqls assigned at specific levels. As revealed, all previous AQM methods used aql. Therefore, the aql value can sometimes be high but can be low in actual queue length. In addition, according to the dropping policy, AQM methods based on the aql value. Once the router buffer handles traffic quickly, the real queue length decreases. If aql is great, formerly received packets are dropped even if the actual queue length is slight [17, 24]. However, most AQM methods use thresholds and target aql, T(aql), which leads to parameterisation problems [18]. To avoid the parameterisation problems that appear in AQM methods, fuzzy logic is agreed upon as a solution for congestion in the control network [25]. Fuzzy logic does not need to deal with parameters [21]. The first use of fuzzy logic was with ATM networks, which developed network performance and decreased packet loss.

Baklizi et al. proposed GREDFL, which is an enhanced AQM GRED method. GREDFL employees' aql and D as input variables for fuzzy logic. Therefore, the GREDFL method enhances the GRED method whilst reducing the widespread of parameter dependency in it. GREDFL uses the same simulation that is used in the AQM GRED method, which uses a discrete time queue model and FIFO packet arrival probability. The performance result for GREDFL method outperforms that for GRED method.

Many other methods use fuzzy logic to improve network performance. Conversely, no method can handle the congestion at early stages to have better performance than the current AQM methods [3, 26, 27]. In this study, FLACC uses two input linguistic variables (aql and PL), unlike GREDFL that uses aql and delay PL. Packet loss is considered one of the most important measures that plays a min role in wresting network performance. Furthermore, the proposed FLACC avoids parameterisation problems and improves packet loss and delay performance measure to gain better performance results than current AQM methods.

III. Proposed FLACC Method

This part presents the design and implementation of the proposed FLACC. Fuzzy logic has been used in FLACC to solve and decrease the limitation of congestion. Fuzzy logic is mainly employed to detect and prevent parameterisation problems in most existing AQM approaches. Also, the proposed method employs aql and PL as congestion indicators to enhance the performance of AQM methods. aql and PL play main roles in expecting the congestion in the buffer. The main goal is to calculate the DP for all arriving packets in the router buffer by using a fuzzy inference process (FIP). To calculate DP, aql and PL are used. Fig. 3 illustrates FIP to calculate the dropping.

The FLACC router buffer is designed without the thresholds existing in AQM methods. Hence, FIP is used to generate the dropping probability, which employs two variables as inputs, aql and PL, to gain one output called DP (see Fig. 4).

The FLACC router buffer is designed without the thresholds existing in AQM methods. Hence, FIP is used to generate the dropping probability, which employs two variables as inputs, aql and PL, to gain one output called DP (see Fig. 5).

The proposed FLACC is designed and implemented to overcome the limitations of current AQM methods and investigate satisfying performance results. This goal is achieved in six stages. Performance measures and parameters are illustrated in Table I.

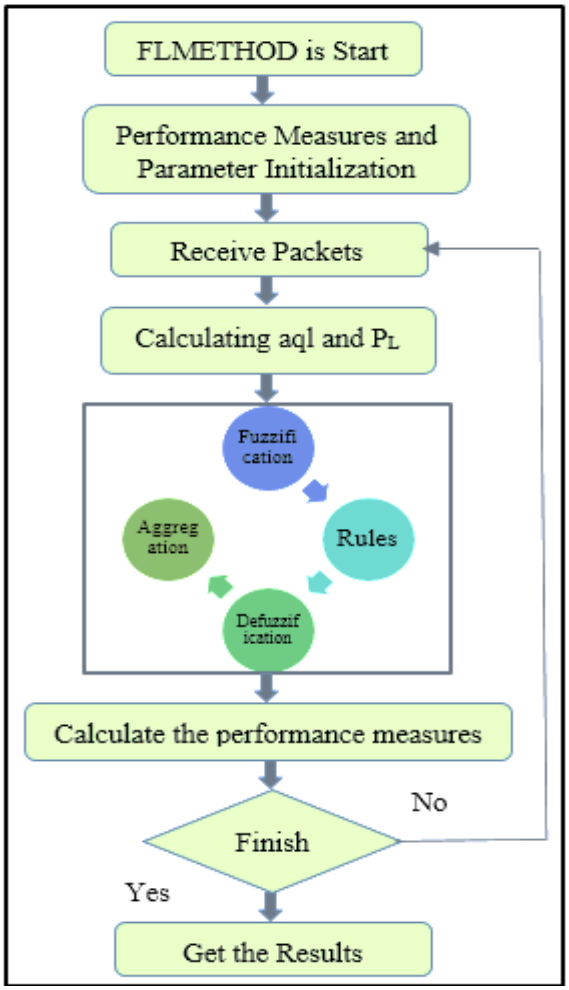

Fig. 4. The Router Buffer in FLACC Method.

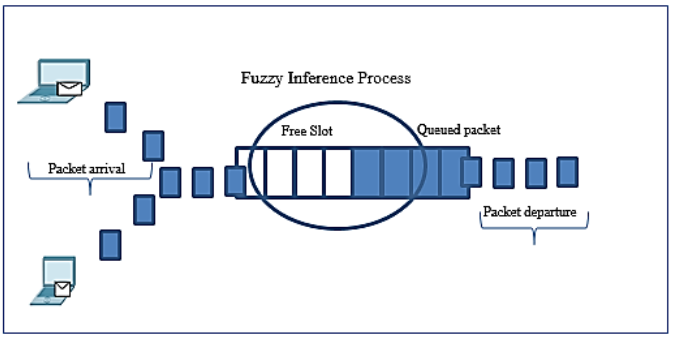

Fig. 5. The Process Stage for the Proposed Method.

TABLE. I. PARAMETERS INITIALIZATION

Parameters	Description	GRED method	GREDFL method	FLACC method
T	Throughput	zero	zero	zero
D	Delay	zero	zero	zero
PL	Packet Loss	zero	zero	zero
mql	Mean Queue Length	zero	zero	zero
DP	Dropping Probability	zero	zero	zero
PA	Packet Arrival	0.33-0.93	0.33-0.93	0.33-0.93
QW	the Weight	2/1000	2/1000	2/1000
Beta	Packet Departure	1/2	1/2	1/2
MP	Maximum Probability	0.1	0.1	0.1
S#	Number of Slot	2millions	2millions	2millions
C	Buffer Capacity	20	20	20
MT	Minimum threshold	3	----	----
MXT	Maximum MT	9	----	----
DMXT	Double MXT	18	----	----

The table is divided into two parts. Some parameters are common with all AQM methods, whereas the second part is customised. Thus, the method depends on fuzzy or AQM.

As mentioned above, on the one hand, some parameter values in Table I are set to equal 0, given that the system in the first stage is idle. On the other hand, the values of other parameters are set similar to those of GRED and FLGRED methods.

In stage two, the router buffer in the proposed method starts to generate the packets, which are moulded using discreet time queue to measure the performance result in a specific time slot. All the input-generated packets in the router are queued in FIFO. In stage three, the performance measures and packet loss are calculated. The aql value depends on whether the router buffer is empty or not. When the buffer is blank, the aql value is considered according to Equation 1.

$$aql = aql \times (1 - q_w)^{\mathrm{n}}, \quad (1)$$

where n denotes # of packets in idle time.

When the router buffer is not empty, the aql value is calculated according to Equation 2.

$$aql = aql \times (1 - q_w) + q_w \times q\_inst, \quad (2)$$

where q_inst represents the current queue length in the router buffer.

The value of packet loss is calculated when the router buffer becomes full or overflows. When the incoming packets reach the buffer in Bursty traffic, the outer buffer starts to build itself and reaches the limit of the router buffer size. Therefore, any arriving packet cannot accommodate space in the buffer, and every packet that arrives can drop directly. Equation 3 illustrates the packet loss.

$$PL = (1 - \mathrm{beta}) \times Pk, \quad (3)$$

where Pk signifies the probability that the buffer is full, and beta denotes the probability of packet leaving or departure.

In stage four, the proposed FLACC fuzzification starts. FIP consists of four steps, namely, fuzzification, rule evaluation, aggregation and defuzzification.

In step 1, fuzzification uses three variables to generate the membership degree. The variables are aql, PL and DP. Each variable contains the following fuzzy set:

aql: {Conservative, Average, Extra}

PL: {Little, Medium, More}

DP: {Slight, Medium, Further}.

The triangular shape is used to represent the input and output variables (see Fig. 6). Fig. 6, 7 and 8 illustrate the membership degrees for the two inputs and one output variable, respectively.

Once the membership degrees are set, the fuzzy set for all input linguistic variables is calculated. The main goal of the fuzzification step is to form the area for each input linguistic variable. In step 2, rules are evaluated. Table II illustrates the rule evaluation for FLACC. Every part is a process that undergoes rule evaluation by obtaining the membership degree for Dp output.

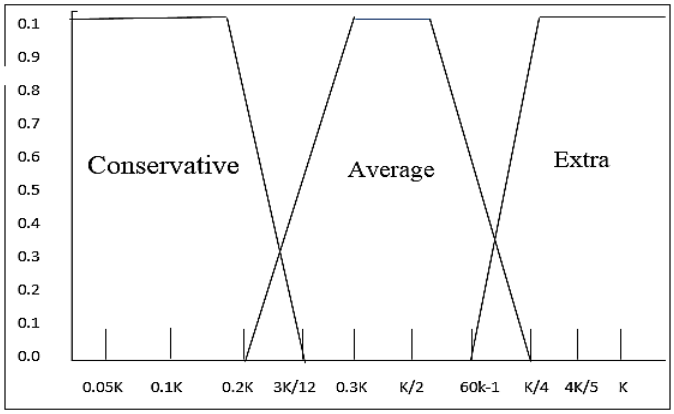

Fig. 6. Membe_rship Function of aql.

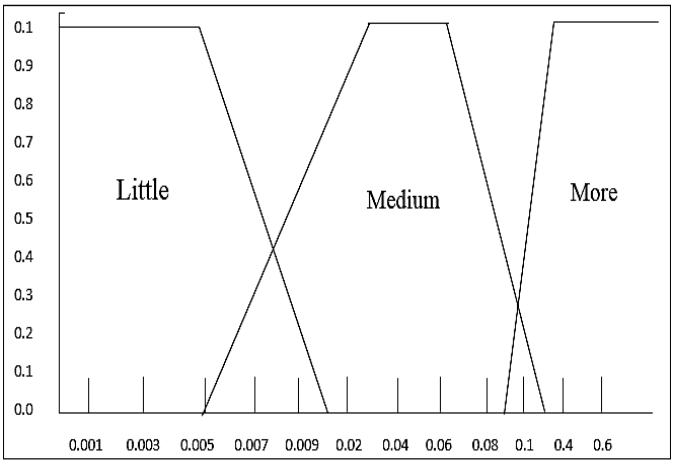

Fig. 7. Member_ship Function of PL.

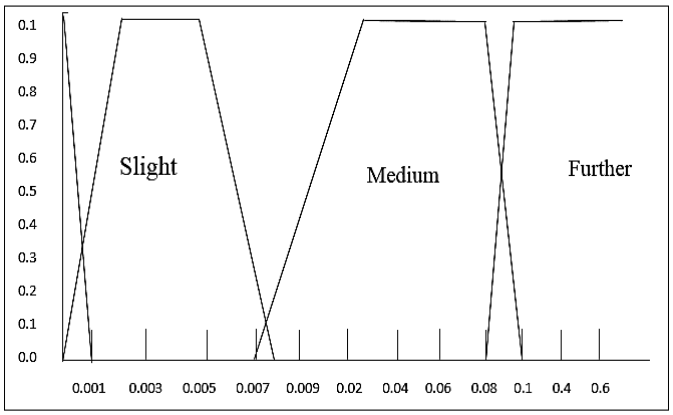

Fig. 8. Member_ship Function of Dp.

TABLE. II. SET OF FUZZY LOGIC RULES

IF aql is Conservative and PL is Little THEN Dp is Zero
IF aql is Conservative and PL is Little THEN Dp is Zero
IF aql is Conservative and PL is Little THEN Dp is Zero
IF aql is Average and PL is Medium THEN Dp is Zero
IF aql is Average and PL is Medium THEN Dp is Zero
IF aql Average is and PL is Medium THEN Dp is Slight
IF aql is Extra and PL is More THEN Dp is Zero
IF aql is Extra and PL is More THEN Dp is Medium
IF aql is Extra and PL is More THEN Dp is Further

In step 3, the output rules are aggregated into a single output rule called fuzzy set, whereby the membership degrees in the previous step are combined.

In step 4, defuzzification is the final step in FIP. Crisp values for all the output variables are generated in the fuzzy set.

The centre of gravity (COG) is used in step 4 [ref mos]. The main goal of COG is to find the centre point in the fuzzy set for all output variables. Officially, COG can be set on the basis of Equation (4). Fig. 9 illustrates the algorithm of the proposed FLACC.

$$COG = \frac{\sum_{x}^{y} A(n) \times n}{\sum_{x}^{y} A(n)} \quad (4)$$

The Proposed FLACC Algorithm
1. Set Fuzzy sets 2. Generate Fuzzy Rules 3. For every packet arrive the buffer 4. If q is zero THEN aql equal (1-w)f(time- q_time) * aql 5. If q <> 0 THEN aql equal (1-w)* aql + w *q 6. PL = (1-Beta) * PK 7. Fuzzy (aql) 8. Fuzzy (PL) 9. Put on Rules(Fuzzy aql, Fuzzy PL) 10. Aggregattion 11. Calculate dropping 12. Drop packet with Dp

Fig. 9. The Algorithm of FLACC.

IV. SIMULATION

This section explains the simulation process prototypical, compared the proposed FLACC with other methods. Discrete-time queue was used in most AQM methods to measure the performance result at any time [28, 29]. The term used was 'time slot,' which means performance measures can be calculated at any time.

The proposed FLACC, FLGRED and GRED methods were realised on a single router buffer in a simulation environment. The router buffer capacity was set to a small value that equals 20 packets. To generate heavy congestion in the router buffer, all methods were implemented as FIFO. The number of slot time used in the simulation environment was 2,000,000 [28]. The first 800,000 slots were used as warm-up and were not tallied in the quantity of the valuation.

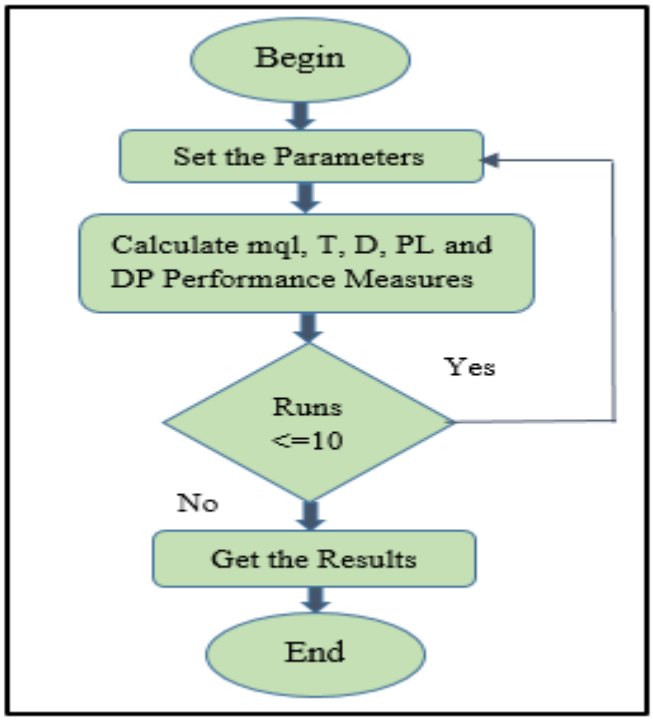

Fig. 10. Simulation Stages.

The simulation used six arrival probabilities (0.18, 0.33, 0.48, 0.63, 0.78 and 0.93), which have been used in several AQM methods [6, 30, 31]. Departure probability was set to 0.5. The proposed FLACC and the compared method were tested and implemented using Java environment under 64 bits Windows 7 (CPU i5 3.10 GHz processor and 4 GB Ram).

In stage 1, the parameters were set to particular values. In step 2, the performance measures were calculated. In step 3, if the runs were less than or equal 10, the process was repeated. Finally, the results were evaluated for all the methods. These stages are illustrated in Fig. 10.

V. Performance Results

The performance evaluation of the proposed FLACC, GREDFL and GRED methods is presented in this section. Furthermore, the proposed method is described in detail according to membership functions, perimeter values and rules set.

The FLACC, GREDFL and GRED methods were measured and compared in five different performance measures (mql, T, D, PL and Dp) to determine the best one.

A. Mean Queue Length

In this section, the performance result of the mean queue length is evaluated. Fig. 11 illustrates the output performances of the proposed FLACC, GREDFL and GRED methods. The experimental is performed using different probabilities for packet arrivals to generate congestion and non-congestion at the router buffer.

The performance measure, mql, investigates the same results for the proposed and compared methods in case the packet arrival probability is less than the packet departure. However, when the incoming packets arrive at high rate probability, such as 0.63, 0.78 and 0.93, FLACC shows a better performance than GREDFL and GRED methods. As a result, FLACC outperforms the AQM compared method when the congestion is present at the router buffer.

B. Throughput

The total number of packets passes the router at a specific time, which is called throughput. The throughput performance measure is an important criterion of computer networks. Fig. 12 illustrates the performance result analysis for the proposed FLACC, GREDFL and GRED methods.

All the methods under the probability of alpha gained the same result, either the packet arrival was less than or greater than the beta. However, all the methods obtained the same value of throughput, which was equal to 0.5. This result was due to the parameter initialisation for the packet departure, as mentioned earlier in the paper.

C. Delay

The performance result evaluation of queueing delay is explained in Fig. 12. The mean queue length in Section 5.1 plays a main role in delay calculation and evaluation. The delay is calculated according to mql and T (see Equation 5).

$$D = mql/T \quad (5)$$

The equation reveals that when the value of mql is small, that of delay is also small.

Fig. 13 illustrates that FLACC outperforms the GREDFL and GRED AQM methods in congestion or non-congestion. When the packet arrival reaches 0.48, 0.78 and 0.93, the proposed method gains enhanced performance result than the compared methods.

D. The Packet Loss

When the received packets reach at the buffer and no space is available, every packet that arrives can drop directly, as the router buffer becomes full and overflows.

Fig. 14 indicates the performance results of FLACC, GREDFL and GRED methods.

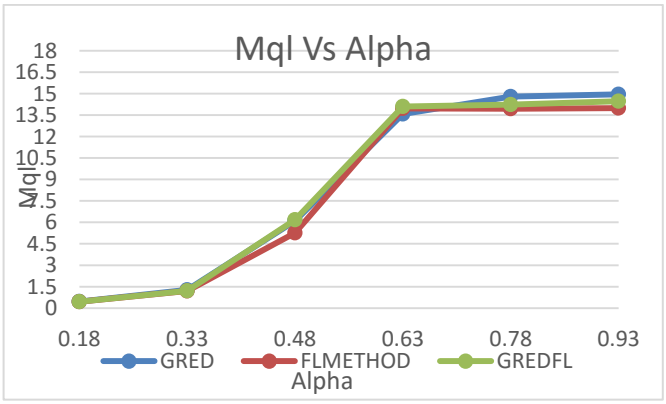

Fig. 11. Mean Queue Length Performance Results.

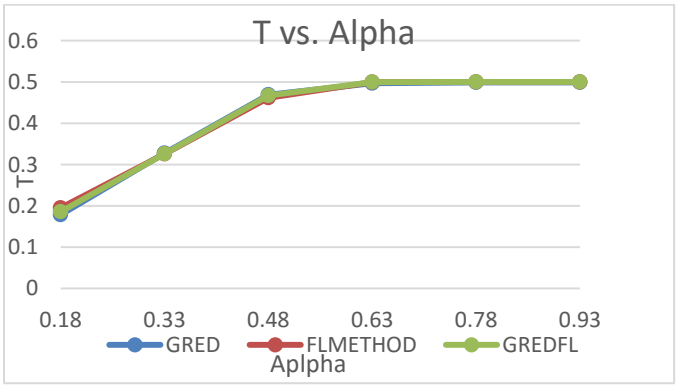

Fig. 12. Throughput Performance Results.

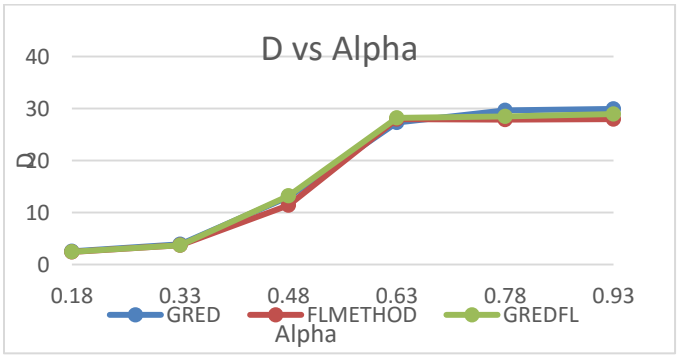

Fig. 13. Delay Performance Results.

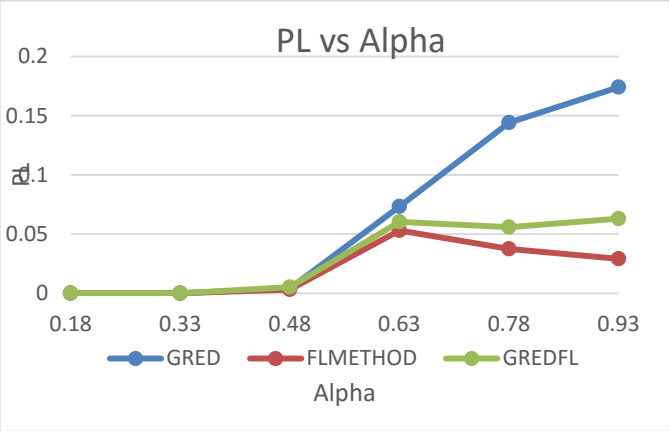

Fig. 14. Packet loss Performance Results.

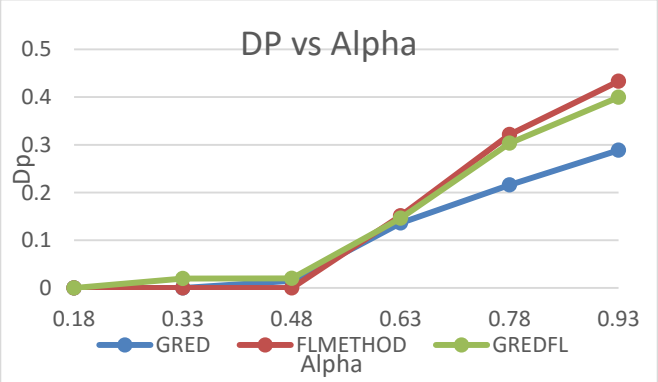

Fig. 15. Dropping Probability Performance Results.

The proposed FLACC has achieved good and least PL performance results, when heavy congestion is present. The router buffer of FLACC overflows less than that of the compared methods, GREDFL and GRED.

E. Dropping Probability

Fig. 15 shows that when congestion exists at the buffer, the FLACC drops more packets at that buffer than GREDFL or GRED methods. Hence, the value of packet arrival is greater than that of packet departure.

Note that the FLACC has lost fewer packets in the router buffer than GREDFL and GRED methods, as presented in the previous section.

VI. Conclusions

One of the main issues that affect computer networks is congestion, which causes the wresting of network resources and performance. Subsequently, the effects include increased queuing buffer, long delays and packet loss. We propose FLACC as a new congestion avoidance method. FLACC is an extension of the GRED AQM method. As parameterisation is a limitation of current AQM methods, FLACC aims to detect and avoid such a problem. aql, PL, and FIP are employed as indicators to discover and prevent congestion at early stages or before the router buffer becomes full. To compare and evaluate their performance results, the proposed FLACC, GREDFL and GRED were tested in a simulated process by using popular processes. The simulation result evaluation showed that FLACC has better performance results than GREDFL and GRED methods when heavy congestion is present. The mql, D and PL decreased with the FLACC, although all the compared methods gained the same T in congestion or no congestion situations. Furthermore, GREDFL and GRED methods dropped fewer packets (Dp) at their router buffers than the proposed FLACC.

VII. Future Work

In future work the current FLACC method applying in wireless area to mechanism the congestion in best effort. To increase the network performance, specially improve the delay and packet loss. In addition, applying the multi class queue using the proposed FLACC method solves the bursty traffic problem.

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Measuring the Effect of Packet Corruption Ratio on Quality of Experience (QoE) in Video Streaming

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***Abstract*—The volume of Internet video traffic which consists of downloaded or streamed video from the Internet is projected to increase from 42,029PB monthly in 2016 to 159,161PB monthly, in 2021, representing a 31% increase in the Compound Annual Growth Rate (CAGR). The market for mobile network operators is unpredictable, fast-paced and very competitive. End users now have more options when choosing service providers. With superior network Quality of Experience (QoE), service providers can increase margins by charging more for better quality. Packet corruption occurs when the receiver cannot correctly decode transmitted bits. This study identified the threshold at which the QoE of video streaming services became unacceptable due to the effect of packet corruption. In this paper, several experiments were carried out on video streaming services, creating disturbances to evaluate the user satisfaction level using the mean opinion scores. Network Emulator (NetEm) tool was used to create the packet corruption experienced during the video sessions and the QoE for different packet corruption percentages was established. From the experiments conducted, we found that user QoE decreased as the Packet Corruption Ratio (PCR) increased. With knowledge of the effect of the PCR, service providers can ensure that the PCR is kept within acceptable limits from end-to-end and this will ultimately lead to superior QoE from end users, which will in turn translate to improved subscriber base and profitability.**

Keywords*—Network Emulator; Packet Corruption Ratio (PCR); Quality of Experience (QoE)

I. Introduction

The growth forecast for the email, data traffic and web category, which comprises file transfers, instant messaging, web browsing, email and other Internet applications, is expected to increase from 9,059PB to 19,538PB per month, in the period from 2016 - 2021, representing a 17% growth in the CAGR. This category contains internet traffic produced by all Internet users. Similarly, in the internet video category which consists of downloaded or streamed video from the Internet, the volume of traffic is projected to increase from 42,029PB to 159,161PB monthly, representing a 31% increase in the CAGR [1]. Fig. 1 shows the expected projection for consumer web, email, data and Internet video traffic.

Presently, over twenty five percent (25%) of the global population uses advanced mobile phones (with numerous functionalities) and other smart devices to access the internet. The web has turned into a fundamental piece of our regular daily existence: Social, business, education and health amongst others. If service providers understand the QoE of popular services, it would improve their long term profitability and also prevent customers churning as a result of inferior QoE [2]. The broad area of Quality of Experience (QoE) is gaining momentum in networks and telecommunications today, but QoE is not an entirely new concept [3]. Quality of Experience (QoE) is defined as "how a user perceives the usability of a service when in use–how satisfied he or she is with a service in terms of, for example, usability, accessibility, retainability and integrity of the service" [4]. It is an estimation used to decide how well a system is fulfilling the users' needs. The concept of QoE is important as it expresses people's perceived value of services. It can be defined in various ways. For example, communication service providers express the concept of user experience as QoE while researchers in Human-Computer interaction (HCI) characterize this concept as User Experience (UX).

"Packet corruption occurs when the receiver cannot correctly decode transmitted bits. Such decoding errors cause the cyclic redundancy check in the Ethernet frame to fail and force the receiver to drop the packet" [5]. Most communication networks experience significant fluctuations in transmission link performance over time. Corrupt packets are normally discarded by the receiver and the information that was sent originally from the source is lost and must be resent. This process of sending and receiving the packets and retransmitting corrupt packets is a costly one for the network operators [6]. It has been established that packet corruption impacts fewer links but can be more severe than congestion. Also, packet corruption rate does not correlate with utilization and link location. Some of the main causes of corruption are connector contamination, damaged or bent fiber optic cables and bad or loose transceivers [5].

In this paper, subjective experiments were carried out in a dedicated laboratory for subjective analysis. A Network testbed was setup in the laboratory to simulate the dynamic behavior of a normal wide Area Network (WAN) using an Ubuntu Linux 18.04 server and a Network Emulator (NetEm) tool. The NetEm tool was used to create artificial packet corruption by introducing single bit errors at a random offset in the packet. This emulates random noise, and can be used to emulate noisy links, such as wireless links.

We conducted experiments with different packet corruption rate percentages and different video content types such as news videos, streaming services like Netflix, YouTube and Footytube. The effect of the disturbances introduced was used to evaluate the user's Quality of Experience. The experiments followed the ITU-T stipulated guidelines for QoE subjective studies [7].

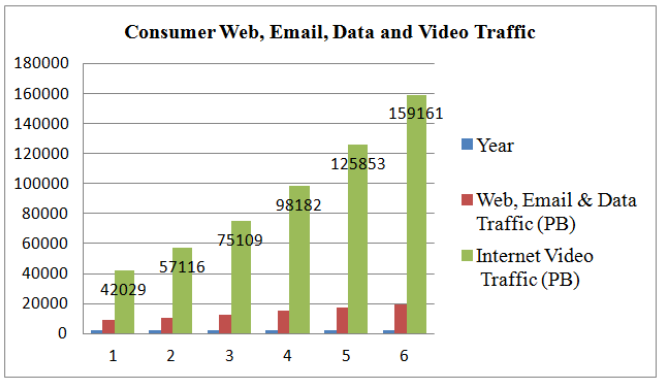

Fig. 1. Consumer Web, Email, Data and Video Traffic.

II. Review of Related Works

Obtaining a rich QoE is possible if service providers can properly keep an eye on how the services and applications are performing from the end-user's perspective. Research has shown that the utilization and acceptance of multimedia services is constantly growing and this provides a massive revenue generation opportunity for operators and service providers. The authors in [8] proposed a video streaming QoE assessment model to evaluate the QoE of video services by utilizing certain network layer QoS metrics. They deployed QoS parameters because network performance ensures and guarantees reliable and efficient delivery of real-time video streaming services. Based on their model, network providers can predict satisfactory QoE for end users.

In [6], the authors analyzed packet corruption pattern from data collected from a sensor network over a period of one year. In this analysis, they considered independent transmission errors and proposed a method to recover information about the original content of a corrupt packet. In [9], the authors investigated challenges with large-scale live video delivery. They achieved this by studying live video delivery that was streamed by over 600 thousand viewers in the United States of America. In analyzing the QoE for the event, they noted that a significant number of users suffered QoE impairments and thus showed lower engagement metrics.

Experiments were conducted by [10] to measure the effect of packet reordering on QoE in video streaming. In their paper, they achieved this using the NetEm tool and video sequences at different packet reorder percentages.

III. QoE Assessments and Experiments

In order to investigate the QoE, an experimental Testbed on which the users were tested for specific scenarios was created. It is important to mention that for consistency, the scenarios were the same for all the users that were tested during the investigation. The experiments were performed in a dedicated laboratory. The procedures for setting up and carrying out the experiments followed the ITU-T recommendations for QoE subjective studies [7].

The subjective assessment directly measured the quality of end user experience by asking human assessors to rate the quality of the video services and applications being investigated. The key benefit of conducting laboratory studies is that the experimenter has full control over the overall evaluation process, including the context and content. In addition to that, those involved in the experiments were directly briefed and observed on the spot, thereby providing methodological and substantive results [11]. The pseudocode for the QoE estimation process is described in Fig. 2 and the As-Built diagram for the experiment setup is shown in Fig. 3.

The NetEm tool was used to create artificial packet corruption by defining rules to corrupt the packets egressing from interface enp3s0 on the Ubuntu Server. To add the traffic control rule to corrupt 10% of the packets egressing from interface enp3s0 we used the command:

tc qdisc add dev enp3s0 root netem corrupt 10%

At the end of the experiments, all the added rules were deleted using the command:

tc qdisc del dev enp3s0 root netem corrupt 10%

```
Input:   Video Streaming Services whose QoE is to be determined
Output:  QoE MOS rankings & User satisfaction level
Begin
         Step 1: Emulate the network for the experiment
         Initialize netem emulator by loading the kernel module
         Emulate the Packet Corruption network condition.
         Step 2: Initialize experiment
         Step 3: Begin Test. Each test should last for a maximum duration of 20 minutes.
         Step 4: At end of experiment, subjects should rate their experiences and provide MOS
         Step 5: Calculate average MOS
         Step 6: End Test. Flush all outbound conditions configured in netem.
End
```

Fig. 2. Algorithm for QoE Estimation.

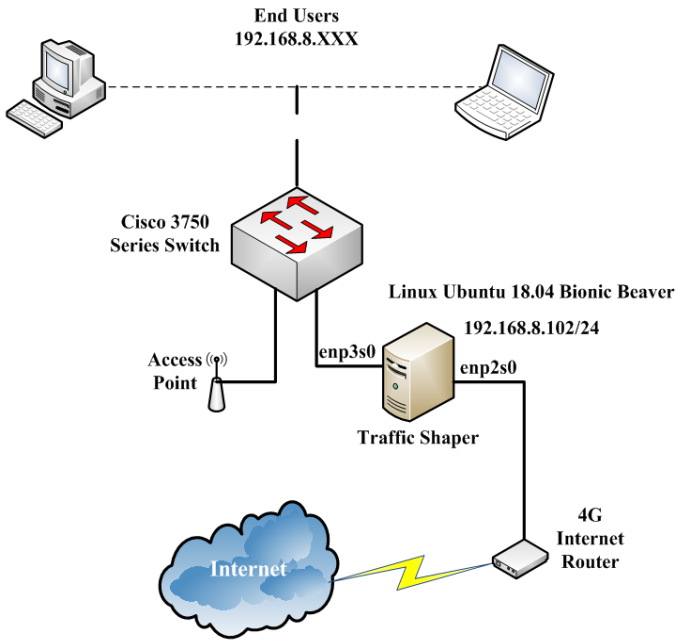

Fig. 3. As-Built Diagram for the Experiment Setup.

TABLE I. MOS DESCRIPTORS

Quality	MOS
Excellent	5
Good	4
Fair	3
Poor	2
Bad	1

The experiments were conducted for different test scenarios and the user perceived QoE was evaluated after each test condition using the MOS (Mean Opinion Score) absolute category scale. The MOS scale has five grades, with each one reflecting users' judgment of the experiment under test. The MOS was used because a complex reporting system may result in low participation rate. Table I shows a typical MOS scale descriptor which was presented to the subjects during experiments.

A. Participants and Procedure

In this experiment, the packet corruption ratio was varied in ascending order of magnitude from 5% to 40% with intervals of 5%. The participants were unaware of the packet corruption ratio at each level. A total of 29 participants, 18 Males and 11 Females were involved in the study. The average age of the subjects was 28. There was a pre-experiment briefing of 10 minutes at the start of each experiment and a 10 minute period after each experiment to debrief the users. The duration of each experiment was for 20 minutes. For the video streaming sessions, popular video streaming services like Netflix, YouTube and Footytube were used. In addition, other video content types, like news pages were used.

IV. RESULTS AND DISCUSSIONS

Table II shows a summary of the results obtained from the experiments and Fig. 4 shows the graph of overall QoE plotted against Packet Corruption Ratio.

A. Discussion

In this study, netem creates the packet corruption by introducing a single bit error at a random offset in the packet. This emulates random noise and it may be used to emulate noisy links for example wireless links. The results obtained are shown in Table II. This study revealed that the MOS was 4.76 at PCR of 5% and this value dropped significantly to 1.55 at 40%. As the PCR increased, the MOS of users decreased correspondingly. It was observed that a negative correlation existed between the PCR and the average MOS.

TABLE II. PACKET CORRUPTION RATIO (PCR) COMPARISON

S/N	Packet Corruption Ratio (%)	Average Mean Opinion Score (MOS)
1	5	4.76
2	10	4.48
3	15	3.72
4	20	3.52
5	25	3.55
6	30	2.72
7	35	1.72
8	40	1.55

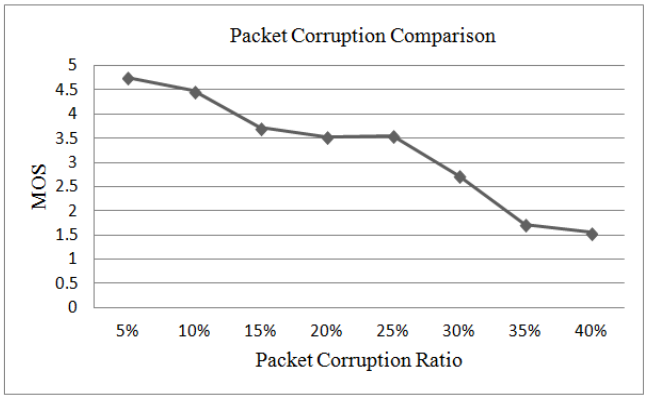

Fig. 4. MOS vs. Packet Corruption Comparison

V. CONCLUSION

In this research paper, several experiments were conducted on video streaming services by creating artificial packet corruption conditions by defining rules to corrupt the packets egressing from ethernet interface the Network Emulator. This was done to establish the acceptable PCR threshold value for the end users. The study showed that at PCR of 30% and above, users were no longer satisfied with the video services and were unwilling to continue using such services. With these available results, network operators can ensure that to fulfill end users' quality expectations and ensure acceptability of their service offerings, the packet corruption ratio should be kept below the acceptable thresholds presented earlier. The study was limited to investigating the effect of PCR on QoE of video streaming services. In future, we plan to examine the effect of other metrics on the QoE. There was restricted subject diversity as the experiments were conducted in a laboratory setting and majority of the participants for the tests were largely researchers and members of the academia. In future, field trials could be carried out or crowdsourcing approaches employed.

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Vision based Indoor Localization Method via Convolution Neural Network

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***Abstract*—Existing indoor localization methods have bottleneck constraints such as multipath effect for Wi-Fi based methods, high cost for ultra-wide-band based methods and poor anti-interference for Bluetooth-based methods and so on. In order to avoid these problems, a vision-based indoor localization method is proposed. Firstly, the whole deployment environment is departed into several regions and each region is assigned to a location center. Then, in offline mode, the VGG16NET is pre-trained by ImageNet dataset and it is fine-tuned by images on a custom dataset towards indoor localization. In online mode, the fully trained and converged VGG16NET takes as input a video stream captured by the front RGB camera of a mobile robot and outputs features specific to the current location. The features are then used as input to an ArcFace classifier which outputs the current location of the mobile robot. Experimental results show that our method can estimate the location of a mobile object with imaging capability accurately in cluttered unstructured scenes without any other additional device. The localization accuracy can reach to 94.7%.**

Keywords*—Indoor localization; VGG16NET; transfer learning; ArcFace classifier

I. Introduction

With increasing demand of location based services, wireless location technology has gradually become a hot research topic. In outdoor environment, global positioning system (GPS), plough navigation systems and cellular positioning technology can satisfy the need of most of the localization. However, in the indoor environment, due to the block of building walls and items, the wireless signal transmission will be affected seriously which will prevent the accurate positioning badly. So other methods designed for indoor localization were proposed.

Among these methods, a strategy using Wi-Fi based fingerprinting location [1] is the most popular one. That is because Wi-Fi signal exists in almost every building in nowadays and it can be easily detected by cell phone which is already equipped almost for every person. So in the Wi-Fi based indoor localization system, additional device is not necessary. But this kind of methods have some critical defects: the value of Wi-Fi signal varies with time and easily affected by multipath effect. Although many algorithms have been proposed already for weakening the impact of these problems, none of them solve these problems well. Blue-tooth based methods [2] have good stability and are not be affected by multipath effect, but it is easily interfered by other blue-tooth devices. UWB (Ultra Wide Band) based methods [3] have strong anti-interference ability, high bandwidth and low power consumption, but its cost is high and the required device is expensive, what's more, the whole localization system is hard to deploy. The localization method based on RFID technology [4] and ZigBee technology [5] also need to deploy complex positioning system. So existing indoor location methods are either easily be disturbed or need support by complex auxiliary positioning system.

A vision based indoor localization method is proposed in the paper. The method uses images to determine the location of the moving object and has the following advantages: one, images in indoor scene are relatively stable than other wireless signals and are not interfered by other devices; two, the system only need a RGB camera on the detected object and no other complex device needed. The author in [6] proposed vision based indoor localization method using nature beacon and artificial beacon. In [7], author proposed a weighted KNN epipolar geometry-based approach for vision-based indoor localization. However, image matching based methods are susceptible to the shooting Angle, illumination changes and other unfixed image information. To find deep layer location features in image, [8] proposed a CNN (Convolutional Neural Network) based semantic scene segmentation for indoor robot navigation. Building information modelling (BIM) was used to construct the image dataset in [9] and a pre-trained

VGG16NET was applied to image feature extraction. But not all the buildings have BIM image dataset. What's more, [9] uses clean scene images for location and it is not suitable for practical application.

On the basis of [9], two major improvements were proposed in this paper. One, in the off-line mode, the VGG16 NET was pre-trained by ImageNet dataset first then fine-tuned by images labeled by location number, this Transfer learning technique allows for over-fitting to be addressed and achieve a robust model with only little training data. Two, original VGG16NET uses softmax as classifier, but when feature confounding occurs, the result will be wrong, for coping with this problem, ArcFace classifier [10] is applied to substitute Softmax classifier.

The rest of paper is organized as follows: Section 2 explains how the proposed algorithm works. Specifically, section 2-A describes the flowchart of our algorithm, section 2-B introduces how we use the VGG16NET, section 2-c explains why we use Arcface classifier. The experimental procedures and results are discussed in section 3. Conclusion and discussion in which show the contribution and limitation of our algorithm are presented in the end of the paper.

II. Vision Based Indoor Localization Method

A. The Flowchart of our Algorithm

Vision based indoor location algorithm in the paper applies VGG16NET to extract the deep layer location feature of images then the image feature was used to determine the location of the mobile object. Firstly, the whole scene is departed into several regions and each sub-region set a location number, the center of the sub-region is memorized. Then, photographs were taken with different angles around the location center. These photographs labeled by location number are then used as the training samples of our VGG16NET, our method include off-line mode and on-line mode.

The main purpose of the off-line mode is to construct the location feature in images of each location center. While training VGG16NET for feature extraction needs large number of images and our training samples are not enough. To avoid the over-fitting caused by the insufficient training dataset, transfer learning is employed. The VGG16NET is pre-trained by ImageNet dataset first then it is fine-tuned by our training samples. In on-line mode, image used for localization is put into the VGG16NET then we get the location feature of the input image. At last, ArcFace classifier was applied to classify locations for the input image. The flow chart of our algorithm can be seen in Fig. 1.

B. VGG16NET

The VGG16NET used in the paper consists of 13 convolution layers, 2 full connection layers and a classify layer. The 13 convolution layers were used to deepen the network then it can be used to extract the deep-layer image features, 5 max pooling layers are employed and they are used to reduce the feature dimensions in order to make the model computationally tractable. Transfer learning was used to improve the generalization ability of the model. The ImageNet dataset is applied to pre-train these first 13 convolution layers and weight parameters of in the network are adjusted and stored. The last three layers consist of two full-connection layers and a ArcFace layer. After the pre-trained step, the whole network is fine-tuned by images labeled with location number. In this step, all the weight parameters are adjusted. The structure of the CNN in the paper is shown in Fig. 2.

The convolution layers consist of 64 3*3 convolution kernels, batch normalization and Rectified Liner Uints (ReLU). The batch normalization was applied to limit large variances into a reasonable scope. In order to skip the unimportant information, max pooling layer which adopt a window with a stride size of 2 is used for down-sampling the feature maps. Full connected layers are employed to the combination of deep features with different weight parameters and random dropout layer are used to cut down some unimportant connection. At last, we can obtain the deep layer image location feature for each location number then we used ArcFace classifier to determine the location number for an input test image.

C. ArcFace Classifier

The original Softmax classifier in VGG16NET does not expand the edge of decision region which would cause wrong classification results when features of different class are similar. In vision based indoor localization, the location feature for adjacent location number may be similar, when the location feature is hard to distinguish, its positioning would be wrong. So the ArcFace layer is applied to substitute Softmax layer in this paper. The difference between the two classsier is mainly because of its loss function.

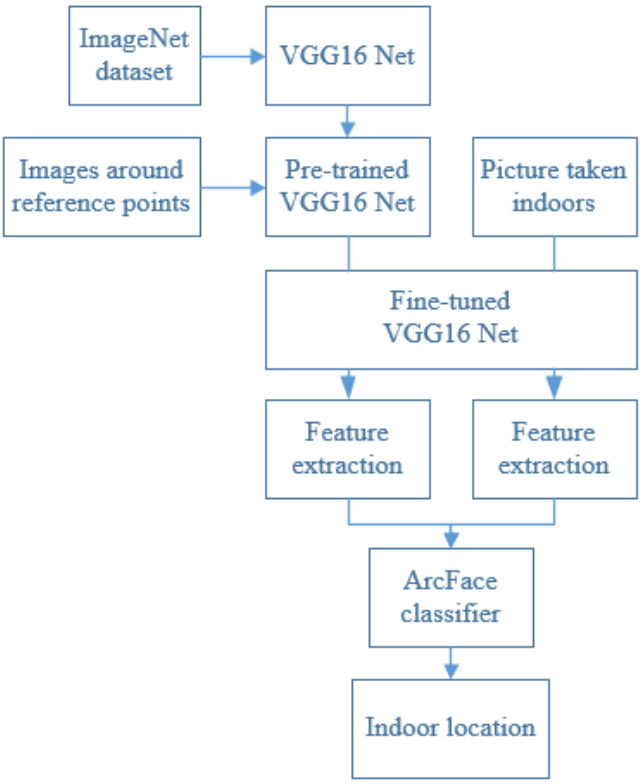


Fig. 1. Flowchart of Proposed Algorithm.

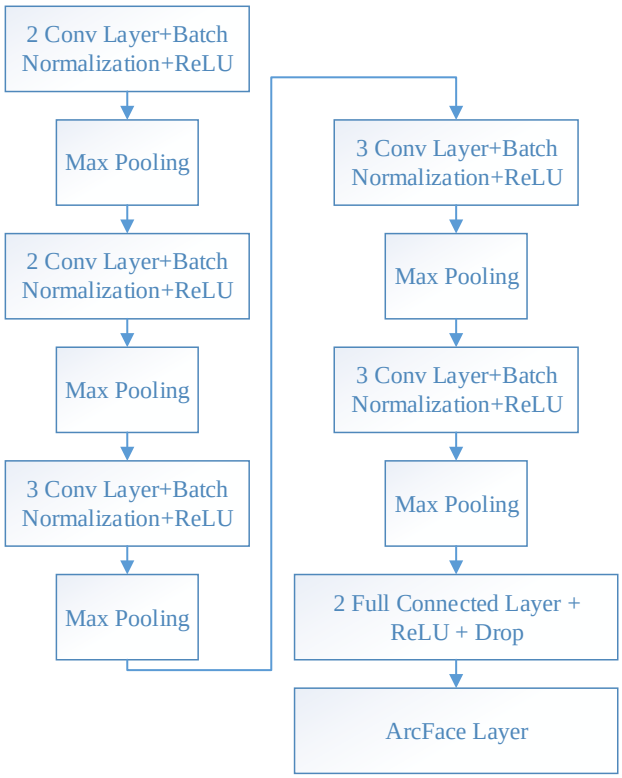


Fig. 2. Architecture of Proposed Convolutional Neural Network.

The loss function of Softmax is:

$$L_1 = -\frac{1}{N}\sum_{i=1}^{N}\log\frac{e^{W_{y_i}^T x_i + b_{y_i}}}{\sum_{j=1}^{n} e^{W_j^T x_i + b_j}} \tag{1}$$

Where x_i represents the feature of the i-th sample in the y_i-th class, W_j is the weight of the j-th column, b_j represents the bias term, N is the batch size and n is the class number. Based on (1), we let $b_j = 0$, $W_j^T x_i$ can transform to $\| W_j \| \| x_i \| \cos\theta_j$, θ_j is the angle between the weight W_j and the feature x_i, we let $\| W_j \| = 1$ and rescale $\| x_i \|$ to s by l_2 normalization. Then, we obtain the loss function as follows:

$$L_2 = -\frac{1}{N}\sum_{i=1}^{N}\log\frac{e^{s\cos\theta_{y_i}}}{e^{s\cos\theta_{y_i}} + \sum_{j=1, j\neq y_i}^{n} e^{s\cos\theta_j}} \tag{2}$$

An additional angular margin penalty m was added into the angular between W_j and x_i to enhance intra-class compactness and inter-class discrepancy. We can obtain the loss function of ArcFace:

$$L_3 = -\frac{1}{N}\sum_{i=1}^{N}\log\frac{e^{s\cos(\theta_{y_i}+m)}}{e^{s(\cos(\theta_{y_i}+m))} + \sum_{j=1, j\neq y_i}^{n} e^{s\cos\theta_j}} \tag{3}$$

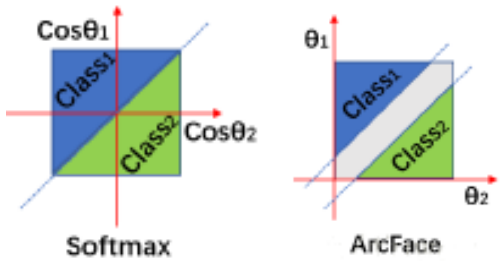


Fig. 3. Decision Margins of Two Loss Functions under Binary Classification Case.

Fig. 3 shows decision margins of two loss functions under binary classification case. The dashed blue line denotes the decision boundary. It can be seen that the Softmax loss function roughly separate the whole plan into two parts and no margin exists between decision boundary, while the ArcFace loss function can obviously afford decision margin between decision boundaries.

III. Experimental Result Analysis

Experiments are carried out in an industrial environment where the whole scene is departed into 9 regions and each region is assigned to a location center, respectively. The assignment of our vision based indoor localization algorithm is to determine the real-time location of the mobile robot in real time. Fig. 4 shows the floor plan of the experimental scene with 9 location centers. The mobile robot used in our experiment is consist of a RGB camera, motion control system and a laptop which is equipped with a single Nvidia GTX 1080 card and an Intel i7 processor. The appearance of the robot can be seen in Fig. 5.

Fig. 4. Floor Plan of the Experimental Scene.

Fig. 5. Experimental Robot Platform.

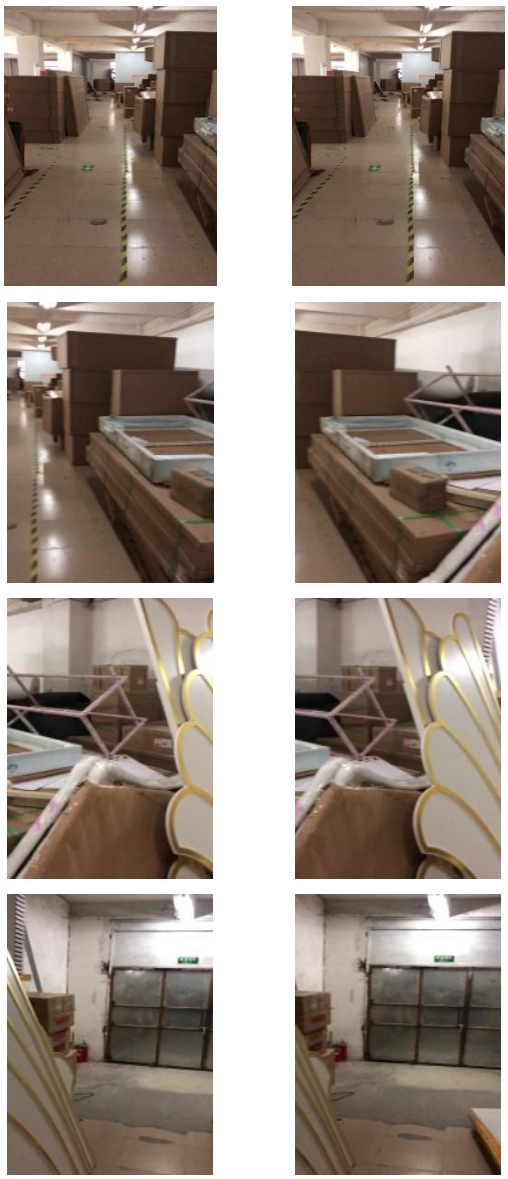


Fig. 6. Some of Training Samples of Location Center "1".

In order to cut down overall training time, the pre-trained VGG16NET is applied directly which can be downloaded in GitHub. The fine-tuning of the network is performed using images labeled location number, these images are taken around the location centers. 100 pictures of each location center were used for training. Fig. 6 shows some of the training samples in location "1".

Fig. 7 shows the change of the model accuracy during iteration processes. We can see that the model accuracy increases for both training set and test set when the iteration time increases. When the iteration time reach to 35, the accuracy of the model would change little during the iteration time increases. The highest accuracy of training set and test set reach to 95.2% and 94.3, respectively. Fig. 8 shows curves of the loss function for training set and test set. We can see that the value of the loss decreases for both training set and test set when the iteration time increases. The lowest loss of training set and test set reach to 0.03 and 0.05, respectively.

After finished the training of the VGG16NET, the model can be used for image based location classification. 21 images of each location center, totally 189 images were used as the experimental objects. Confusion matrix was used to depict the experimental results which were shown in Fig. 9. Fig. 9(a) is the classification result of ArcFace classifier, Fig. 9(b) is the classification result of Softmax classifier, rows in the figure mean the actual location of tested images, and columns mean the estimated location tested by algorithms. When the estimated location meet the actual location, i.e. the check of left diagonal, means that the estimated location is right. Numbers in these checks mean the time of correct classification, numbers in other checks mean the time of wrong localization and on which location. For example, in the fourth line of Fig. 9(a), the actual location is location "3", the correct estimated time is 18, and the wrong estimated time is 3, one time in location "6" and two times in location "8". Totally, the correct classification time for Softmax classifier is 172 and the wrong classification time is 17, the accuracy rate of softmax classifier is 91%. When comes to ArcFace classifier, the correct classification time is 179 and the wrong classification time is 10. The wrong classification mainly concentrate on the center of the building where images taken in these location points are similar to images taken from other location points, sometimes even human eyes can't identify. The accuracy rate of ArcFace classifier reaches to 94.7% which is 3.7% higher than the Softmax classifier.

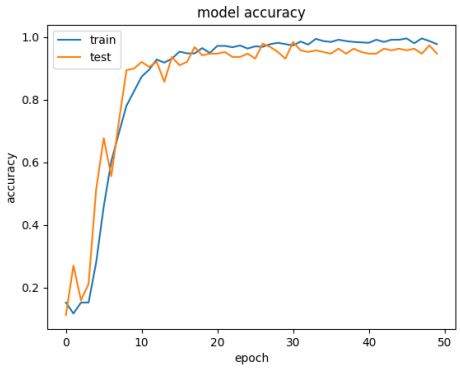


Fig. 7. Curvers of the Model Accuracy for Training Set and Test Set.

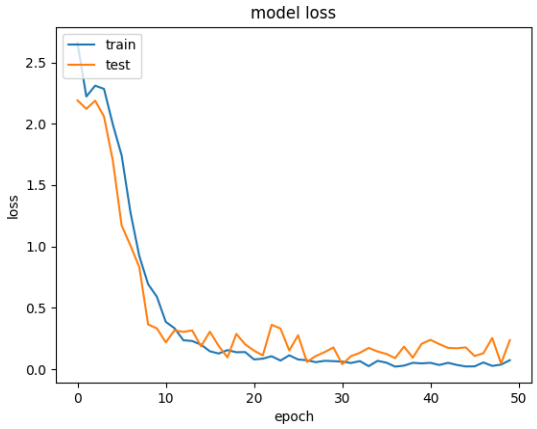
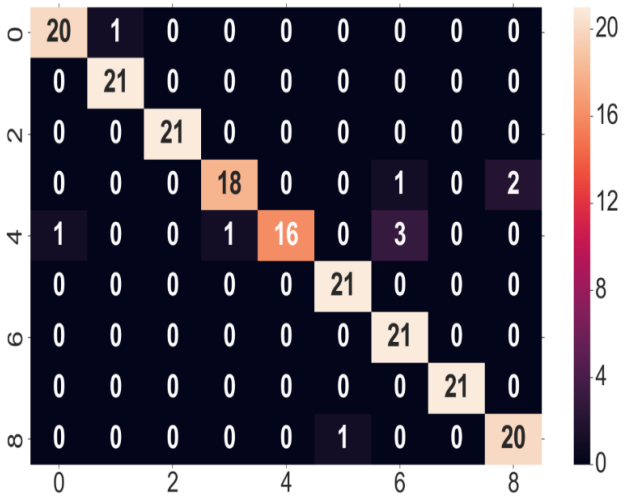
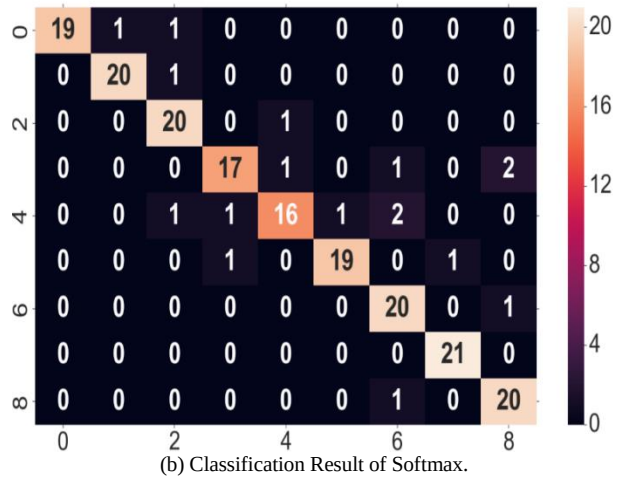


Fig. 8. Curvers of the Loss Function for Training Set and Test Set.



(a) Classification Result of ArcFace.



(b) Classification Result of Softmax.

Fig. 9. Expermental Result Depicted by Confusion Matrix.

IV. Conclusion and Discussion

A vision based indoor location method is proposed in this paper to avoid problems (easily be disturbed by other signals or complex devices needed) hard to be solved in existing indoor location systems. CNN is applied to extract the deep positioning feature in image to solve the problem of existing vision based method easily be disturbed by superficial image feature. Transfer learning was employed to pre-trained VGG16NET then it is finetuned by images labeled by location number. After that, ArcFace classifier is used to substitute Softmax classifier to solve the problem of the error classification in feature similar circumstances. Experimental results show that our method can acquire high accuracy location of object with imaging capability in cluttered unstructured scene. But when the location information of the input image is obscured badly, our method would fail, such as when a human stand closely in front of the camera. What's more, the positioning accuracy of the algorithm in this paper is not high, that is because if location centers are placed closely, location features of nearby location center will hard to identify.

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Fixation Detection with Ray-casting in Immersive Virtual Reality

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***Abstract*—This paper demonstrates the application of a proposed eye fixation detection algorithm to eye movement recorded during eye gaze input within immersive Virtual Reality and compares it with the standard frame-by-frame analysis for validation. Pearson correlations and a sample paired t-test indicated strong correlations between the two analysis methods in terms of fixation duration. The results showed that the principle of eye movement event detection in 2D can be applied successfully in a 3D environment and ensures efficient detection when combined with ray-casting and event time.**

***Keywords*—Eye Movement; Eye Tracking; Virtual Reality; Fixation Detection; HMD**

I. Introduction

Analysis of eye movement data recorded by eye trackers has been shown to be a valuable tool for psychological research and diagnosis. During the eye-tracking experiment, the data sample represented as a stream of data exhibits specific behaviors which can be used to detect oculomotor events. It is important to determine specific limits or thresholds before the detection of eye movement events. These thresholds of eye movement event detection have no standards or accurately defined values, but can be determined by trial and error, or by experience, or taken from literature in the same paradigm, which may lead to subjective results [1-3] whether the analysis is performed manually or algorithmically.

However, the algorithms used in eye movement research are based on general principles for detecting oculomotor events. The gaze coordinates (x, y) for a given stimulus display are calculated and represented as a data sample, and, based on the spatial and temporal characteristics of these gazes, events can be detected. Frequent events include fixations and saccades, along with their associated characteristics such as fixation duration and saccadic amplitudes. A fixation is represented as a group of consecutive gaze points resulting from the eye stopping to look at a target, where the fixation duration is the time window between onset and offset of a fixation, which in most studies, is bounded between 200 ms and 400 ms and is rarely less than 100 ms. A saccade is represented as spaced-out gaze points where no visual processing can occur because of the rapid jumps in the eye movement towards a target.

The spatial characteristics of eye movements are the velocity and dispersion of eye gazes, and the duration is a temporal characteristic. To measure the velocity, it is necessary to sample gaze data at a high rate. This allows the velocity between consecutive gaze points to be calculated. Thresholds can then be applied to this velocity to detect and classify events. Fixations are indicated by low velocities between consecutive gaze points (<100 °/s), while saccades are indicated by high velocities (>300 °/s) [3]. Dispersion is also used to identify fixations and saccades, because tightly clustered data points tend to indicate a fixation, whereas data points which are more widely spread spatially tend to indicate a saccade.

However, in eye movement research, detection algorithms are often not described clearly, and their measurements rely mainly on the hardware specification and the research objectives. This makes it challenging to perform a meaningful comparison of algorithms for movement detection. To address this problem and create a road map of algorithmic validation, in [3], Salvucci and Goldberg proposed a novel classification of fixation identification algorithms based on the principal techniques used in implementations of these algorithms.

On the other hand, the majority of eye movement research utilizes commercial analysis tools provided by the eye tracker manufacturers. In commercial software, the detected oculomotor events, mainly fixations, represented using different gaze visualization techniques include scan paths, areas of interest (AOI), and attentional or visual maps.

A. Eye Movements in Virtual Reality

Virtual reality (VR) technology provides the opportunity to conduct, in realistic environments, experiments which would be very expensive or unsafe to conduct in real environments. Thus, the ability to use eye tracking and detect oculomotor events within these environments will open a new door for researchers to dig deep inside human behavior and user experience (UX), to support training and education, and many other applications, in safe and convenient environments.

On the other hand, despite all the advantages of VR for scientific research, creating these environments is still a significant challenge that consumes a lot of time and effort, as a given research goal typically requires specific visual objects and characters. Also, studying eye movements within a specific experiment necessitates defining the visual behavior to be measured and its significance to the research question: primarily, the eye metrics, such as fixation or pupil size, and their characteristics that are associated with the visual behavior. Consequently, combining VR environments with eye-tracking technology will increase complexity and will be time-consuming.

One of the possible solutions to reduce the time and cost in such a complex environment is to use off-the-shelf components and suitable VR environments from previous related studies. However, eye-tracking studies have mainly represented the gaze coordinates as (x, y) on a 2D display representing the contents of the environment. This means that the tools available for visualization and analysis in this context are not adequate for analysis of eye movements in a 3D environment [4], as they can only be applied to scenes which are composed of frames. However, measuring and analyzing eye movements in immersive VR is a relatively new sub-field in eye-tracking research. In this area of research, the stimulus within the VR environment contains visual objects or scenes for specific purposes, and the experiment aims to test a hypothesis through objects which are known as objects of interest (OOI) or through AOI in the scene, similar to the principles of experiments with head-mounted eye-tracking systems. Eye-tracking studies in real environments are still time-consuming, as the display will be video recorded, and must then be examined manually, such as frame-by-frame. Frame-by-frame analysis is an appropriate tool, acceptable in the analysis of eye movements on video records. However, it has a significant drawback for researchers conducting an eye-tracking experiment involving video recording, where the gaze coordinate must be checked in each frame to see whether it is located on a specific predefined AOI or not. This is very time-consuming, so only small samples can be taken [5][6]. The same method of video recording and manual analysis [3][7] is applied to eye movement within the VR environment.

Currently, there is an ongoing effort to develop eye-tracking systems that are adequate to emerge with immersive VR. In 2018, embedded 60-120 Hz eye trackers in high-performance head-mounted displays (HMDs) appeared on the ground: these are FOVE [8], SMI and Tobii [9]. These HMDs with embedded binocular eye trackers (HMD-ET) include multiple infra-red sources and use the pupil-corneal reflection technique to measure the distance from the corneal reflected light "glint" to the extracted pupil center, then calculate the gaze direction by measuring the changing distance between the glint and the moving pupil center to allow free tracked head movements in the helmet. The accuracy and reliability of these new devices depend on all the hardware and software technologies utilized to build these systems. Until now, this emerging technology has been still in development, and there are many challenges for researchers in designing adequate environments and software tools for analysis and visualization of eye movements that utilize and take advantage of such technology. Unfortunately, this technology also has no technical limitation on producing massive quantities of hardware and tools with a variety of techniques like previous eye-tracking systems [4], and most manufacturers do not disclose the algorithmic solutions used in their products. Therefore, the difficulty of comparing studies of eye tracking in 3D will continue, just as in 2D classical studies.

Unlike eye tracking in a classical 2D environment, several streamed data can be generated using HMD-ET that can be used for more in-depth analysis of eye movements and additional understanding of human behavior compared to classical 2D. Point of regard (POR), for example, is the gaze point mapped onto the projected image on an HMD screen, identical to 2D gaze, but with a 3D vector ray-casting representing the direction from a virtual camera origin for both eyes to the POR. Another example is 3D vectors representing the actual direction of both eyes when looking at the physical world and their origins at the center of the eyeballs. Currently, reading these streamed data is only possible by creating a client-side file dump [10].

This paper proposes a simple methodology to detect eye fixations and OOI using HMD-ET in current VR environments. To validate the proposed algorithm's analysis of eye movements within VR, its outcome was compared with the outcome of a frame-by-frame gaze location analysis.

II. Previous Works

Duchowski et al. [11] introduced novel techniques for binocular eye tracking within VR. These are 3D calibration techniques and 3D eye movements analysis techniques. The study was conducted on an aircraft inspection simulation training application. Stellmach et al. [7] proposed a set of gaze visualization techniques with a prototype toolkit for supporting eye movement analysis in static 3D environments similar to heat maps and scan paths that are used in gaze visualizations for 2D contents, and investigated the usefulness of their techniques. In another similar recent study in [12], the gaze fixations were mapped onto a geometrical model to generate 3D attention volumes similar to heatmaps. Boukhalfi et al.'s [13] work in progress presented the development of a multimodal brain–computer interface (BCI) at the Montreal Philippe-Pinel Institute for different studies related to forensic psychiatry (including the integration of eye tracking glasses within a 4-wall CAVE-like VR environment). The majority of the previous studies including VR and eye tracking used a semi-immersive VR approach, as in [14], which showed that average 3D gaze errors between 3D object and the eye gaze increased linearly with the distance of the virtual planes. In contrast to this, HMD-ET captures the eye from a close distance that leads to a more accurate gaze estimation.

III. Methodology

A. Hardware and Software Requirements Specification

Despite the progress in GPUs, it is still challenging to render 3D graphics in a resolution adequate for the resolution of the eye. Currently, minimum requirements should be considered for the machine that will be used to run the VR environment and the eye tracker plugin. Also, it is important to provide a high-frame-rate VR [12] to avoid VR sickness. The hardware requirements are: an msi laptop with GeForce GTX 1080 8 GB, Intel Core i7 7th Gen (2.80 GHz), 16 GB RAM, connected to an HMD from VIVE HTC [15] with a field of view (FOV) of 110 degrees and a resolution of 1080 × 1200 pixels per eye and a refresh rate of 90 Hz. The HMD is integrated with a pair of eye trackers from SensoMotoric Instruments (SMI) which track the subjects' gaze in the 3D environment with a typical accuracy of 0.5° [10]. Each eyepiece of the goggles is trimmed with a small ring of a miniature infrared camera and six infrared lights positioned in a circle around each eye. This tracker works with the C++/C# SDK for various VR engines. The setting platform is the

Windows 10 operating system, and the 3D application development tool used is Unity. Eye-tracing data were recorded in the Unity VR engine relative to an origin coordinate at the upper left corner of the HMD screens, as specified by the SMI plugin documentation [10]. The recorded eye-tracking data were sent to a dump file which was processed by the proposed algorithm implemented in Matlab. The tools used for video recording and manual analysis were ApowerREC, Kinovea, and MS Excel. Finally, SPSS was employed for statistical tests.

B. Participants

Five participants volunteered in the experiment, three males, and two females, age 26 ± 8.2 years (mean ± SD). All participants are healthy with no motor or neural abnormalities.

C. Stimuli

The task scene is a VR environment used to demonstrate gaze interaction with Unity provided by SMI including an eye-tracking plugin. The scene is presented as a room with cube-shaped objects on the walls. Although in VR all visual objects are named, some of the cubes were defined ahead as OOI (i.e., MiddleObj, CornerObj, RightMidObj, LeftObj, LeftMidObj, and BackObj) for the purpose of comparison between the eye movement analysis methods. The eye-tracking plugin software represented the participant's gaze point on the display as a small pointer-like blue circle (gaze cursor).

D. Experiment Procedure

Each participant was given a brief explanation of the simple task that they would be required to complete, in which they wear the helmet, complete the calibration procedure and look around for one minute, fixing their gazes on the objects on the walls freely and unaware of the defined OOI. After each participant understood the instructions for the task, the HMD-ET was adjusted to the participant and then calibrated. A standard calibration procedure was used in which each participant was instructed to stare at a red point which appears at the beginning and keep tracking its movement. Once the calibration procedure has succeeded, the virtual room was presented to the participant's view.

In each participant session, in the same order, the eye-tracking data streams were recorded in a dump file during the experiment. A complete video recording of each participant's view contents was also saved. When a task was completed, the dump file was analyzed offline using the proposed algorithm, and the video record was analyzed using manual gaze location detection in frame-by-frame analysis.

E. Eye Movement Data Analysis Methods

1) Proposed dispersion-based algorithm: The proposed methodology to detect fixation and OOI in VR environments using HMD-ET is based on several of the previously known principles in the literature. The main steps of the proposed algorithm are reading streamed data, denoising, fixation detection, and OOI hit detection. The eye-tracking data stream was collected into the dump file and the algorithm was implemented in Matlab according to the previously determined measures.

a) Measurements used in the implementation: In streamed eye movement data, there is always some noise or undesirable data depending on factors such as the equipment used and the environment. Therefore, denoising is essential to remove such data. Here, denoising was achieved by eliminating data points corresponding to blinking. When a participant's eye is closed, the pupil diameter is zero, so the tracker returns the coordinates (0, 0). Also, any data points outside the boundaries of the environment were eliminated.

To detect gaze fixation, the concept of dispersion was used, based on its usage in 2D fixation detection. Choosing a suitable threshold depends on the hardware and the experiment specifications. Here, an HTC HMD was used with a FOV of 110 degrees and a resolution of 1080 × 1200 pixels per eye. In most human computer interaction (HCI) eye-tracking studies, the typical fixation size is one degree, so to convert the threshold of one degree into pixels using Pythagoras' theorem, one degree is approximately equivalent to 15 pixels in this display. The precision of the fixation size, which can be determined by the dispersion between the coordinates of successive concussive gazes, can be varied depending on the required task and the virtual objects in the VR.

The distance between two concussive gazes is calculated using the Euclidean distance of the gazes' coordinates (x, y) as follows:

$$\text{Distance} = \text{sqrt}((x_2 - x_1)^2 + (y_2 - y_1)^2) \quad (1)$$

According to the literature, the minimum duration of a fixation is 100–250 ms. Again, the duration can be varied depending on many factors such as stimulus complexity and the required task to be accomplished. The HMD used has a 90 Hz refresh rate, which means 90 gazes recorded per second, so nine gazes can be recorded in 100 ms. Consequently, when more than nine gazes are found within the determined threshold (15 pixels), it forms a cluster, which represents a fixation within the corresponding timestamp.

The 3D vector of ray-casting originating from the participant's eye is traced to check if an OOI is hit when the event occurs. When fixation forming coincides with the ray-casting hitting the OOI, the fixation is assigned to the OOI.

b) The output of the algorithm: In addition to detection of the start and end time, and the number of gazes in each fixation, the proposed algorithm was able to detect small fixations that are difficult to detect manually. It also shows the corresponding OOI that was fixated on. Graphical representation of the timeline shows the gazes in the XY plane during a time slot and the corresponding 3D vector of the ray-casting direction in the 3D environment (sample shown in Fig. 1).

2) Frame-by-frame analysis: The video software Kinovea used for the frame-by-frame analysis shows 1800 frames per minute for each participant's view content. Each frame was checked for the gaze cursor location and was coded into a spreadsheet by assigning the gaze to one of the predefined visual objects that overlay the gaze cursor. When the gaze cursor was located outside those OOI or when there was no signal for the gaze cursor, it was assigned to No OOI (sample shown in Fig. 2).

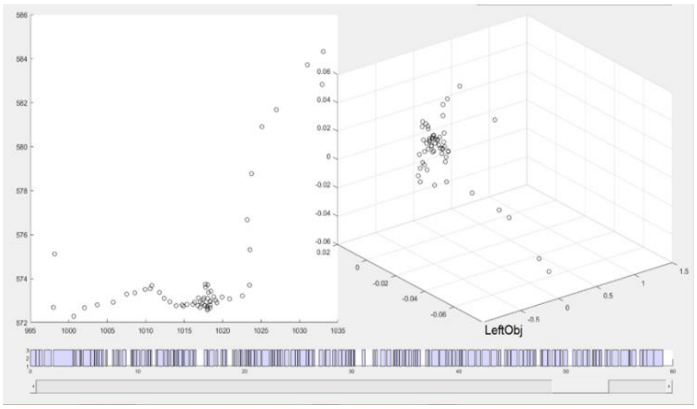

Fig. 1. Gaze Direction and POR Gazes in the Selected Timeslot.

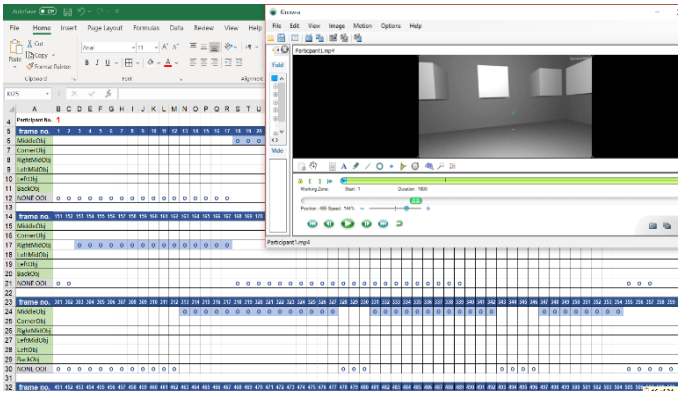

Fig. 2. Frame-by-Frame Analysis Spreadsheet.

The minimum fixation threshold implemented in the first method was 100 ms, which is equivalent to 3 frames of 1800 frames per minute. Therefore, at least three consecutive frames should be encoded for the same OOI to form a fixation, and the number of frames indicates the length of the fixation duration.

F. Comparison Method

The number of fixations in the frame-by-frame analysis is much less than in the algorithm, as long fixations were recorded in the frame-by-frame analysis in cases where there were several consecutive small fixations on the object, which can only be detected by the algorithm. Also, sometimes consecutive fixations were found in the frame-by-frame analysis due to the absence of the gaze cursor signal. To compare between the two methods, the total duration of fixations on each corresponding OOI for each participant was calculated in MS Excel, using the number of frames in frame-by-frame analysis and using the number of gazes in the proposed algorithm. The fixation durations were compared in SPSS to validate the proposed algorithm with frame-by-frame analysis using a Pearson correlation and a paired sample t-test.

IV. Results

Pearson correlations were carried out for each pair of OOI (e.g., MiddleObj in algorithm output versus MiddleObj in the frame-by-frame output). The results of the correlation analysis are shown in Table I.

Very significant and strong correlations are exhibited between the two methods. This indicates that both methods are very similar in terms of fixation duration. The exception to this is LeftObj, which exhibits a non-significant correlation ($p = 0.098$). However, the correlation coefficient is nevertheless strong ($r = 0.808$).

A t-test was used for evaluating differences between the two methods. This procedure is summarized in Table II. No significant differences were found between the two methods for any of the paired OOIs. As such, it can be said that the output of the proposed fixation detection algorithm and the frame-by-frame analysis are statistically identical in terms of fixation duration.

The fixation duration percentage results from the fixation detection algorithm and the frame-by-frame method, for the six OOIs in the analysis, can be found in Fig. 3, confirming that the proposed analysis algorithm produces similar results to the frame-by-frame analysis.

TABLE. I. Pearson Correlations

Pair (OOI in the algorithm – OOI in frame-by-frame)	**Correlation**	**Sig.**
MiddleObj - MiddleObj	0.984	0.003
CornerObj - CornerObj	0.929	0.022
RightMidObj - RightMidObj	0.980	0.004
LeftObj - LeftObj	0.808	0.098
LeftMidObj - LeftMidObj	0.940	0.018
BackObj - BackObj	1.000	0.000

TABLE. II. Paired Samples T-Test for the Proposed Algorithm and Frame-by-Frame Analysis

Pair (OOI in the algorithm – OOI frame-by-frame)	**Mean**	**Std. Dev.**	**Std. Error mean**	**t**	**Sig. 2-tailed**
MiddleObj-MiddleObj	171.1	931.3	416.5	0.411	0.702
CornerObj-CornerObj	1337.8	1379.8	617.1	2.168	0.096
RightMidObj-RightMidObj	424.4	973.5	435.3	0.975	0.385
LeftObj- LeftObj	395.6	1698.7	759.7	0.521	0.630
LeftMidObj-LeftMidObj	735.6	1094.3	489.4	1.503	0.207
BackObj- BackObj	-86.7	193.8	86.7	1.000	0.374
df = 4					

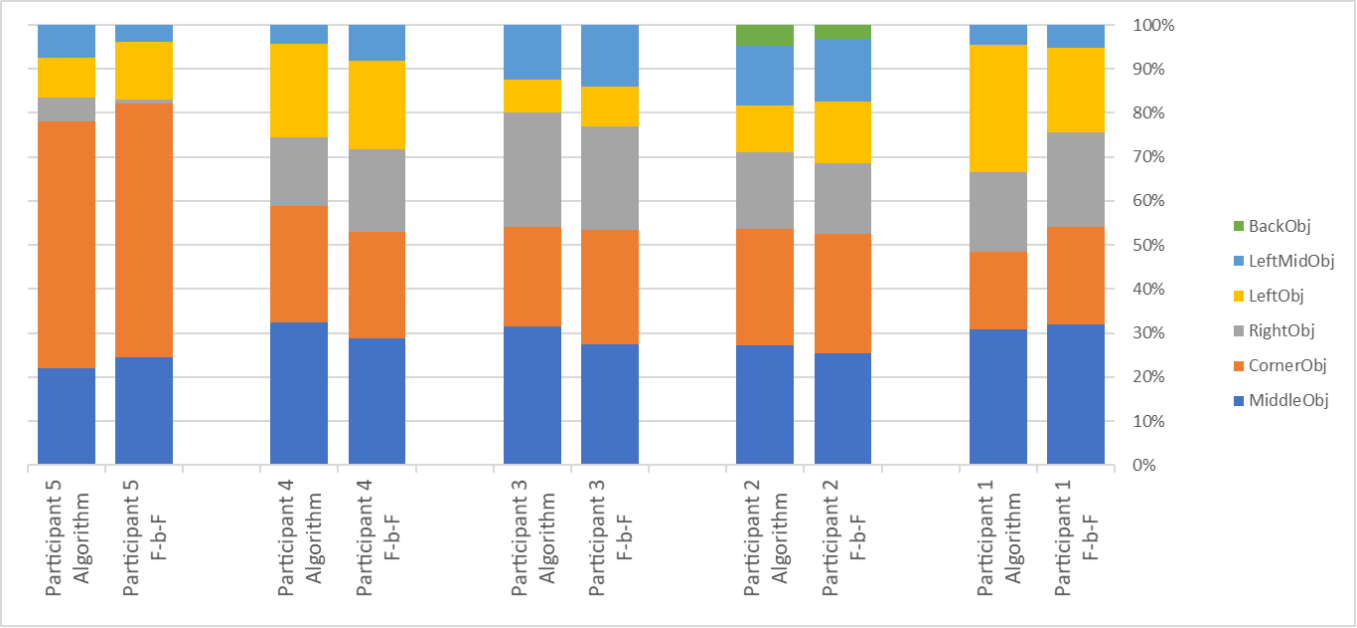

Fig. 3. Duration Percentages for OOIs in the Fixation Detection Algorithm and the Frame-by-Frame Analysis.

V. Conclusion and Future Work

Eye movement analysis in VR is still a new research area among eye-tracking studies. This paper has presented an initial investigation of eye gaze within the VR environment and a demonstration of a proposed fixation detection algorithm within current VR environments using SMI HMD-ET. Continued development of the proposed algorithm will be considered for future eye movement analysis studies.

In VR, the position of a pixel within a projected scene will reflect different objects each time rendering occurs. One of the solutions to this issue lies in the ray-casting originating from the participant's eye; it is a convenient technique for finding where the user is looking, thus providing the opportunity to study the user's gaze behavior in VR environments. This ray-casting can be utilized to get the hit information for an OOI, when it exists, and determine the gaze direction inside the VR world.

The results of the proposed algorithm indicate the possibility of utilizing the same principles of eye movement analysis algorithms that are applied to the spatial or temporal characteristics of gazes in 2D to study eye gaze behavior in a 3D environment, in conjunction with the time of events and ray-casting, in many applications. Nevertheless, further investigation into the data stream recorded by eye-tracking devices in immersive VR needs to be considered in future work to utilize these data streams efficiently.

To validate the proposed algorithm, the result of its analysis was compared with frame-by-frame manual analysis, which is employed and recognized as a tool to analyze eye movement data with the similar technology of eye-tracking devices mounted on the head like eyeglasses. The results of both methods correlated very highly, using Pearson and paired t-tests. Nevertheless, there are many differences between the two methods that cannot be ignored. Despite the effort and time spent on the frame-by-frame analysis, it is not useful in determining an actual number of fixations and their spatial and temporal characteristics. With such drawbacks, algorithmic solutions for eye movement analysis are required. While this is difficult in the natural environment using head-mounted eye tracking, the integration of eye tracking with immersive VR represented in HMD-ET technology provides an alternative solution for many cases. With the tremendous advance of graphics, VR offers a safe and controlled realistic environment, which has allowed many costly or dangerous research studies to be transferred from nature to the laboratory and eye-tracking studies are not an exception with the emergence of this HMD-ET. Moreover, it opens the door for discoveries and research in different multidisciplinary fields.

Lastly, it is worth mentioning that many applications or studies require a precise selection of visual objects from within a dense visual field or an estimation of fixation depth, such as in joint attention and visual communication studies. These requirements require the search for a new paradigm and innovative approaches to analyzing eye movements within the depth of the virtual environment.

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Traceability Establishment and Visualization of Software Artefacts in DevOps Practice: A Survey

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***Abstract*—DevOps based software process has become popular with the vision of an effective collaboration between the development and operations teams that continuously integrates the frequent changes. Traceability manages the artefact consistency during a software process. This paper explores the trace-link creation and visualization between software artefacts, existing tool support, quality aspects and the applicability in a DevOps environment. As the novelty of this study, we identify the challenges that limit the traceability considerations in DevOps and suggest research directions. Our methodology consists of concept identification, state-of-practice exploration and analytical review. Despite the existing related work, there is a lack of tool support for the traceability management between heterogeneous artefacts in software development with DevOps practices. Although many existing studies have low industrial relevance, a few proprietary traceability tools have shown a high relevance. The lack of evidence of the related applications indicates the need for a generalized traceability approach. Accordingly, we conclude that the software artefact traceability is maturing and applying collaboratively in the software process. This can be extended to explore features such as artefact change impact analysis, change propagation, continuous integration to improve software development in DevOps environments.**

Keywords*—Software traceability; visualization; comparative study; DevOps; continuous software development

I. Introduction

Software system is an asset that contributes to enhance products or services. Change of a software system is inevitable as the requirements are evolving over time. Technology improvements, environmental changes, modifications in legal bodies and many factors affect requirement changes. Therefore, a continuous system update is required to cope with the artefact changes by preserving the value of the software. Hence, considering the usage of resources, time, cost and effort, software evolution is preferred over building a new software system to manage the changes [1]. Generally, software evolution is identified as a maintenance task due to new change requests during the Software Development Life Cycle (SDLC). The software evolution mainly depends on the type of software being maintained, the development processes, and directly affects the related software artefacts.

Software artefacts are the intermediate by-products used in each stage of the SDLC that contribute towards the outcome of an intended product. For instance, Software Requirement Specification (SRS), non-functional design reports, design diagrams, source code, test cases, test scripts, bug reports, walkthroughs, inspections, configuration files, build logs, project plans, risk assessments and user manuals are some of the artefacts in the SDLC [2][3]. There are different forms of relationships between the homogeneous and heterogeneous software artefacts. Some artefacts may be highly coupled, and some may depend on other artefacts in different degrees, unidirectionally or bidirectionally. Thus, software artefacts consistency management helps to fine-tune the software process. The incomplete, outdated software artefacts and their inconsistencies mislead both the development and maintenance process. Thus, artefact management is essential such that the changes are accurately propagated to the impacted artefacts without creating inconsistencies. Traceability is the potential to relate artefacts considering their relationships [4][5]; thus, a solution for artefact management. Being an active research topic, many studies have discussed the different aspects of traceability, tool support in different scopes and domains.

At present, DevOps, that unifies the process between the development (Dev) and operation (Ops) teams, has become a popular software development practice. DevOps environment supports to build, test and deliver the product at a high demand and results in faster evolvements of the products [6][7]. The concepts, Continuous Integration (CI) and Continuous Delivery (CD) encourage to accept frequent changes at any phase of the SDLC in DevOps practice [8]. Thus, artefact management is essential to achieve in DevOps environments to avoid artefact inconsistencies. However, it is challenging to ensure traceability with maximum automation due to frequent integrations. Further, the practical use of artefact traceability in DevOps is not widely in use due to the limitations in existing traceability techniques, tools and automation capabilities. Thus, auditability and traceability are challenging in DevOps [9].

We present a survey on artefact traceability management in DevOps practice. The traceability concepts and terminology are described in Section II. Section III and Section IV explore the traceability creation techniques and related visualization methods, respectively. Related traceability management studies in DevOps practice with the conceptual traceability models are discussed in Section V. Moreover, the tool support to manage traceability is explored in Section VI. Section VII explores the traceability evaluation methods using quality aspects and network analysis. The associated challenges and limitations are discussed in Section VIII. Finally, Section IX concludes the survey with the identified suggestions and possible future directions for traceability support in DevOps practice.

II. Background

A. Concept of Traceability

A software system is a combination of several artefacts that evolves through a certain software development process model.

It is important to manage the relationships and dependencies between these software artefacts to maintain the consistency of the product. The outdated artefacts can lead to artefact inconsistency, synchronization issues and lack of stakeholders' trust in artefacts [10]. Thus, it is essential to manage the artefact traceability in software development with DevOps practices that involve frequent Continuous Integration and Continuous Delivery (CICD).

Traceability provides a logical connection between the artefacts of the software development process. It is important to maintain the traceability among both homogeneous and heterogeneous software artefacts throughout the SDLC stages covering the requirements gathering, design, development, testing, maintenance and deployment. For example, the ability to track the relationships between requirements and their sources is essential to revise the initially gathered set of requirements [2]. This concept was initially used as a method of managing requirements artefact during the requirements engineering phase [11]. Generally, traceability is defined as the ability to follow the life cycle of a software requirement both forward and backwards and overcome the inconsistencies during software development [4]. Thus, each alteration occurs in each requirement is traced among other requirements and changed accordingly based on the impact. These traces are used in the requirement validation and verification processes.

Center of Excellence for Software and Systems Traceability (CoEST) has defined traceability as "the ability to interrelate any uniquely identifiable software engineering artefact to any other, maintain required links over time, and use the resulting network to answer questions of both the software product and its development process". They have not limited to requirement traceability and have declared traceability in terms of other artefact types such as design documents, source code and test cases with the deployment of an experimental traceability environment for researchers called TraceLab [12]. Traceability is defined as the ability to trace the dependent items within a model and trace the corresponding items in other models [13]. As a result, currently, traceability is used not only in requirements management but also for other artefact types in different software development methodologies like Model-Driven Development (MDD) [14]. This wide range of adaptation of traceability shows its importance in improving software quality, maintenance, evolution and reuse activities.

B. The Terminology of Software Artefact Traceability

Traceability refers to the ability or the potential of tracing a change propagation among artefacts in a software system. For a given trace, there can be one or many possible trace paths, while each trace path has a source and target artefacts. An artefact may be a source for a given trace path and a target for another trace path, simultaneously. A trace link or a traceability link is a relationship between a pair of artefacts. All trace links generated between two sets of artefacts are referred to as a trace relation [4]. A trace set is the sum of all generated traces and traceability graph is used to visualize all the relationships. A traceability graph is a traceability network when the edges are directional, or the nodes are embedded with a weight. Further, traceability maintenance manages the consistency of the artefacts and updates the traces for a given change.

Different traceability classifications exist in the literature as shown in Fig. 1. One such classification is automatic or manual, based on the automation level of the traceability process. Another classification is forward or backwards, that is based on the direction of the traceability path [4]. Forward tracing follows subsequent steps such that from requirements to code; whereas backward tracing follows antecedent steps such that code to design or requirements artefacts. Artefact-level is another criterion that classifies traceability as horizontal or vertical. Horizontal tracing reflects homogeneous artefacts, which are at the same level of abstraction such as tracing between different versions of requirements [15]. Further, this can be sub-classified based on the direction such that horizontal forward tracing or horizontal backward tracing. Tracing heterogeneous artefacts that are in different levels of abstraction, such as the requirement to code, is considered as vertical tracing, which can be either vertical forward tracing or vertical backward tracing. Proactive and reactive tracing is another categorization based on stimuli behaviour. In reactive tracing, the traces are created on demand by responding to a stimulus to initiate the trace capture. Whereas in proactive tracing, traces are created in the background without explicit response to any stimulus [4]. The traceability link generation techniques (see Section IV) that are based on these categories are selected by considering aspects such as the problem domain and the behaviour of the software system.

C. Traceability in DevOps Practice

The DevOps concept represents the collaboration of the development and the operational teams [6][9]. DevOps eases the project team management with communication, understandability, integration and relationships by bridging the gap between the development and operational teams. This CICD process increases the rate of change and deploys the features into production faster [16][7]. Thus, DevOps-based software development improves the quality, customer experience and supports simultaneous deployment in different platforms. The associated cross-functionality behaviour enables the early identification of ambiguities, reduction of the error fixing time and reduction of the problem complexities. The importance of DevOps towards the business aspect is also significant to shorten the development life cycle, increase the release velocity and improve the Return on Investment (ROI) by achieving a higher customer satisfaction [6]. Further, rich collaboration and performance-oriented culture encourage the ability to research and innovate within projects. However, the Internet of Things (IoT) and Microservices architecture are identified to be challenging in DevOps [9].

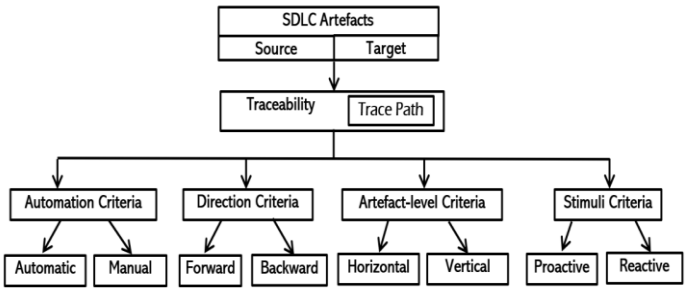

Fig. 1. Summary of Traceability Classification.

DevOps environments associate five main principles: continuous planning, continuous integration, continuous delivery, continuous testing and continuous deployment [6]. The CI process integrates work frequently that leads to multiple integrations per day and deploys effectively [17][18]. Generally, CI verifies the integration using build automation by early detection of integration errors. The ability to trace the artefact changes is essential to notify feedback at an integration failure [19]. Thus, it is important to have software artefact traceability support for the CI process to handle changes.

III. Traceability Establishment

A. Information Retrieval and Data Pre-Processing

In software development, different types of artefacts are considered for traceability creation such as requirements to design, requirements to source code and test cases. For instance, requirement traceability shows the mapping of the requirements to other stages of the SDLC; design traceability refers the ability to trace design and requirements to design rationale for verifying and maintaining the architectural design [20]. In a DevOps environment, the design traceability helps to identify the change impacts, trace design evolution, relate design objects and analyse the cross-cutting concerns.

Generally, Information Retrieval (IR) methods and data pre-processing are considered as pre-requisites to the traceability establishment process. Software artefacts consist of different formats such as the requirements in natural language, design artefacts in different Unified Modelling Language (UML) notations and source code artefacts in programming languages. Thus, pre-processing techniques should be applied to extract the required data as an initial task towards the generation of traceability links. Most of the time, the textual content in the artefacts provides descriptive details about its informal semantics. The frequently involved pre-processing steps for textual-based requirements artefacts are Natural Language Processing (NLP) tasks such as tokenization, text normalization, anaphora analysis, morphological analysis and stemming [4][21]. It is assumed that the artefacts are conceptually related if their textual contents are similar Thus, trace links can be created among them. Hence, the other types of artefacts can be pre-processed with different file readers, UML parsers and programming language specific parsers.

IR methods enable the extraction and analysis of the embodied textual contents in artefacts with a less pre-processing effort [4]. It minimizes the cost of traceability link recovery as it does not consider predefined vocabulary or grammar. The key steps in a generalize IR process that follows a pipelined architecture are: (1) document parsing, extraction and pre-processing, (2) corpus indexing with an IR method, (3) ranked list generation and (4) analysis of candidate links. Moreover, most IR related techniques are Vector Space Model (VSM), Latent Semantic Indexing (LSI) and Term Frequency-Inverse Document Frequency metric (tf-idf) and they have provided better performance outcomes in the literature [22].

B. Traceability Establishment Approaches

Different types of approaches have been used in the literature to generate traceability links between software artefacts. This section discusses the widely used software artefact traceability establishment approaches and Table I states a comparison of these approaches.

TABLE I. Traceability Establishment Approaches

Method	Description	Advantages	Limitations
Rule-based	Defines a rule set based on artefact attributes. Manages traceability with rule re-evaluation [23].	Works well with artefacts such as requirements, use cases, object models [23].	Structural changes are hard to identify [4].
Hypertext	Manage traceability using XML markup specifications [23].	Works with requirements and code [4].	Weekly supports the other types of artefacts.
Event-based	Manage traceability using publish-subscribe links and event-based subscriptions [24].	Maintains dynamic links.	Scalability issues in maintaining the dynamicity of the traceability [24].
Constraint-based	Provides a set of constraints which must not be violated by traceability links [25].	Views artefact types as constraints among them.	Difficult to refer all the traceability links with the constraints [25].
Transformations	Uses incremental [26] and graph-transformation based methodologies.	Suited for model-based software systems [26].	Difficult to apply to artefacts that are not generated using MDD [26].
Goal-centric (GCT)	Manages the change impact of non-functional requirements. Use soft goal interdependency graph and traceability matrix [27].	Ensure quality by assessing the change impact of functional vs. non-functional aspects [27].	Lack of scalability and tool support [30].
Model based	Manages traceability using template-based models [28].	Supports different artefact types [28].	Lack of support towards non-MDDD [28].

Rule-based traceability generates different types of trace links between artefacts based on the semantics and the grammatical features of their words [29]. First, the traceability link generation rules are defined based on the attributes of the artefacts and then the traceability maintenance phase re-evaluates the rules. Moreover, rule-based approaches can be combined with event-driven approaches. Thus, the traceability maintenance can be conducted in two phases: (1) recognizing changes based on events and (2) re-evaluating the rules that governing link updates [26]. However, these rule-based traceability techniques are not applicable to all types of artefacts rather than requirements and source code [23].

Hypertext-based traceability uses an underlying XML representation along with the conformance analysis. This is suitable for complex and versioning of traceability links [4]. However, hypertext-based traceability support technique is also limited to software artefacts such as requirements and source code [23].

The event-based approaches consider the events occur during the software development activities to maintain the traceability links. For example, the deletion of an artefact can be made as a trigger to delete all the connected traceability links. Maro et al., have addressed this using a similar conceptual technique; publish-subscribe mechanism, that connects traceability maintenance tasks to events [26]. However, this technique has scalability issues [24][25].

Various other approaches that can be used to establish traceability are available in the literature. The model-based traceability establishment approach manages the inter-relationship of models using XML representations, without narrowed only into UML, Business Process Model and Notation (BPMN), feature models and systematic review for architecture to code traceability [27][28]. Constraint-programming is another approach that declares the valid rules for traceability links [25]. Here, the traceability links that are not referenced by constraints are considered as consistent by default. The transformation-based approaches [26], mainly graph-transformations are used to generate traceability links based on the artefact transformations. However, these approaches are not widely used in practice. The Design Decision Tree (DDT) provides the ability to connect requirements to architecture decision and design elements under the traceability establishment. The traceability model presented in [20], has addressed the traceability in a design rationale model using the conceptual UML notations. However, it captures relationships between only two entities, architecture rationale and architecture elements. Further, a scoped-based approach was explored by Patricia et. al., [30], that emphasizes the current status of considering traceability in a given situation rather than presenting all the traces. This has been an attempt to minimize the traceability cost by engaging a manageable minimal set of links.

IV. Traceability Visualization

Software artefact traceability visualization helps the decision-making process to analyse the relationships among artefacts. However, it is challenging to visualize many traceability links and paths among software artefacts in real-time with the evolving inter-relationships. The challenges include scalability and visual clutter related issues. Although there are data visualization techniques and tools to analyse large temporal data, the selection of an optimal representation depends on different properties in the traceability links. This section discusses traceability visualization techniques and Table II summarizes a comparison of these techniques.

Traceability matrix is used to record the trace relations. Initially, requirements traceability matrix has used to associate requirement artefacts during the requirements engineering process [31]. It shows the associated or dependent pairs of artefacts using the trace links [4]. The work done by Cleland-Huang has shown the possibility of increasing the cost of traceability creation and maintenance by using this technique, although the row-column structure is simple. Since this representation is easily readable by the stakeholders, a single repository is sufficient to document both forward and backward traceability results, which is an advantage in terms of storage. However, representing many artefacts and trace links using a traceability matrix is less practical due to the complexity in access, search and update operations.

The hierarchical tree is a node-link based representation that uses lines to connect parent and child nodes. This representation is easily understandable and communicates a hierarchical structure. There are two sub-approaches in this hierarchical tree visualization. The first approach has edges between relevant children nodes and group edges using the hierarchical edge bundling technique. However, this method has the drawback of visual clutter with a larger number of traceability links [35]. The second approach directly adds traceability links as children of leaf nodes. Further, this technique is used to represent detailed dependency information of an item. In related work [31], hierarchical tree visualization is used as a supplement for Tree-map visualization to illustrate the detailed information on each trace.

TABLE II. Traceability Visualization Techniques

Method	Features	Advantages	Limitations
Lists [32]	Show data in 1-dimension, sequentially.	Efficiency due to simplicity.	Limited for a small-scale data due to a single dimension.
Traceability matrix [31] [33][34]	Stores data in 2-dimensional grid structure.	Well-represents a small set of artefacts.	Impractical to represent a larger number of trace links.
Cross-reference [31]	Represents data in a table structure.	Provides a list of related links for an artefact.	Hard to show the full trace structure. Scalability issues.
Tree-map [33][35]	Uses a tree data structure to represent data in 2D.	Represents a large tree by optimum display space.	Hard to communicate with the layers. Complex for a larger set of traceability links.
Hierarchical tree [35]	Node-link representation to show data hierarchically.	Gives trace dependency data. Simple to understand.	Visual clutter when a larger number of traceability links are involved.
Traceability graph [33][36][37]	Show data as nodes, links as edges.	Visualizes structured data with relations.	Limit the graph view for excessive nodes. Performance issues.
Sunburst and Netmap [32][33]	Use a radial layout.	Browse, navigate with user orientation.	Not filter the visualization links.

Traceability graph visualizes a trace set in a node-link format, where trace artefacts as nodes and trace links as edges [4]. The associated visual clutter can be reduced and can enhance the readability of the traceability graph by using colour codes for nodes and edges based on their type, category and direction [38]. The traceability outcome can be analysed by graph traversal and graph analysis methods. Moreover, network analysis methods discussed in Section VII can be applied to analyse these network graphs. However, this technique has performance issues when there is an excessive number of nodes and links.

Among many other visualization techniques, lists are a single dimension primary approach that can be applied for a small set of data. This technique shows efficient performance due to its simple structure [32]. Cross-reference is a tabular structure that represents a list of related links for a given software artefact. However, this technique does not support to obtain an overall traceability representation [31]. Tree-map approach represents trace data in a 2D tree structure and supports a larger set of data. However, the communication among each trace artefacts by traversing the tree tends to be complex [33]. Further, Sunburst and Netmap visualization [32] is a radial layout representation approach.

Most of the traceability visualization techniques have slightly considered model driven features; thus, there is a limit of supporting to a range of software types [36][37]. Many related works have addressed issues such as visual clutter and scalability [32][33] and several tools are integrated with a specific Integrated Development Environment (IDE). However, most of the studies have not addressed different types of software artefacts, as they have considered a certain type of artefacts such as either requirements or source code. Thus, there is a potential need for a generic software artefact visualization methodology that can accommodate artefact representation independent of its type and scale.

V. Traceability in Practice

A. Models for Traceability in DevOps Practice

Although there are some attempts in the recent literature to adapt traceability into Agile environments, traceability management in DevOps practices has not been addressed well. A generic Agile Traceability Model (ATM) for managing Non-Functional Requirements (NFR) has presented by Firdaus et al. [39]. They have traced the effects of the frequent Functional Requirement (FR) changes on NFRs such as security and performance. This model is based on an example ATM [4] that trace requirements, source code and test cases and an NFR traceability metamodel that links the stakeholders and the requirement grouping component of the project. Each artefact and its elements of the FRs are used to trace NFR with a mediate association component. Fig. 2 shows the integration of ATM (blue in colour) and NFR traceability metamodel (grey in colour). Here, the code is backtracked to the requirements through testing. It is required to have test cases for NFRs without adding code to the overall model. Thus, the impact of development changes is traced using test cases. This conceptual model has been implemented as a prototype. Although the average value of precision and recall of the process model is 0.46, they have stated that the integration is mapped correctly.

A traceability approach named Trace++, that transforms a traditional software development to Agile environments has been proposed in [40]. They have addressed four transition issues such that (i) amount of rework per sprint, (ii) high-level understanding of a project scope before starting a sprint, (iii) lack of NFR documentation, and (iv) losing management control. They have considered extended information as shown in Fig. 3 when transforming to an Agile environment.

Another semi-automated traceability prototype for Agile development is proposed in [41], with the intention of achieving reusability of requirements artefacts. This work is based on an extension of an existing metamodel named TmM model [42]. The authors have identified reusable traceability links with the automated traceability link generation and Agile integration approaches as shown in Fig. 4. The user story change process is started when a change to a user story in the Agile team backlog occurs. If the responsible link is not found in the link repository, then the link generation process obtains rules from the metamodel and sends the result to the link maintenance process that modifies or removes the impacted links. The automated link generation process requires a manual confirmation from an authorized Agile team member via the link generation reviewer in IDE.

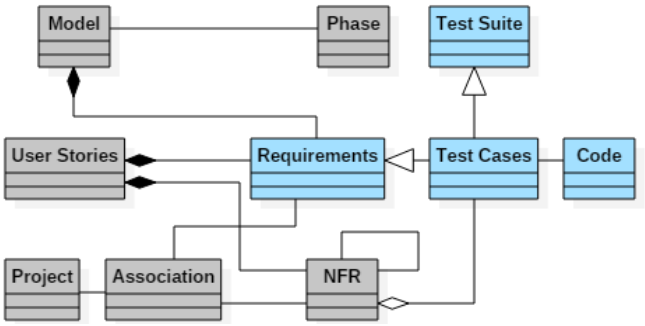

Fig. 2. Proposed NFR Agile Traceability Model [39].

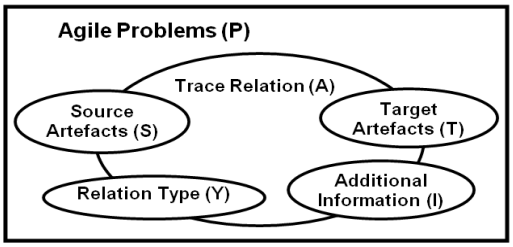

Fig. 3. Trace++ Traceability Solution Structure [40].

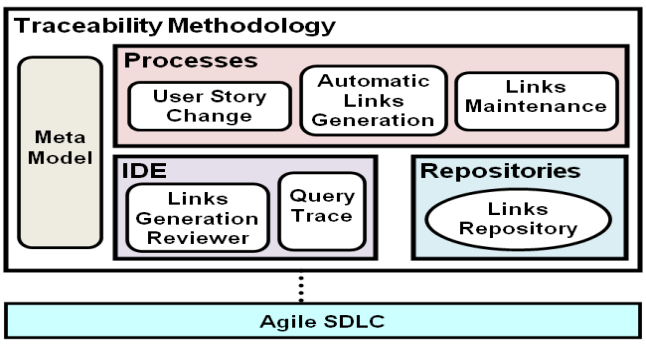

Fig. 4. Traceability Methodology for Requirements Reuse in Agile [41].

Generally, in a DevOps environment, distributed cloud platforms integrated software projects are monitored using logs and runtime information. These data are scattered in large-scale projects, due to the use of multiple tools and dashboards, hence hard to identify accurately. A traceability approach to monitoring these data in a DevOps environment has been proposed using explicit links between runtime information and source code in [43]. This work has used an online context graph to show the connections such that edges denote the implicit connections among information fragments. The conceptual model of this solution is shown in Fig. 5. A prototype of this context analytics model has been evaluated using cloud applications. The cost associated with the artefact pre-processing is low in this approach, as it considers runtime information with short textual artefacts. The results have shown a 48% reduction of efforts required in analysis steps and an average reduction of 40% for the required inspected traces.

A heuristic named SPEQTRA is proposed to locate the traces of automated tests in the CI process [44]. This approach enables the efficient continuation of a project when a test case is failed during the DevOps practice. Fig. 6 shows the trace execution of successful and unsuccessful test cases. This approach executes each test case records the traces and identifies the closet item set to transform traces to sequences via SPEQTRA. Then, the classes with sequences are ranked using the Jaccard similarity coefficient based on the fault likelihood to localize the classes with faults.

Similarly, another test case artefact-based tracing approach that supports CI for the automotive industry domain is proposed in [45]. They have used black-box testing following the input and output signals through process controllers as shown in Fig. 7. Every keyword in the test suites are used to trace the most suitable tests for a given CI task and a mapping table is maintained for the selection.

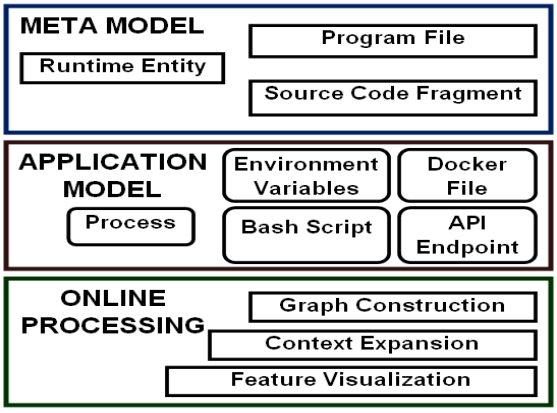

Fig. 5. DevOps Context-Based Analytics Conceptual Model [43].

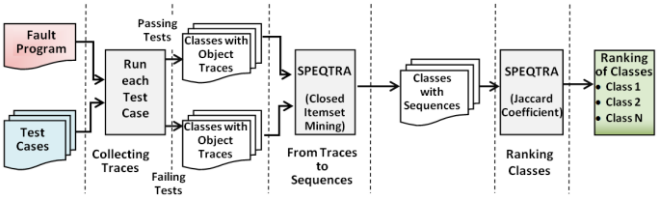

Fig. 6. SPEQTRA Heuristic Workflow [44].

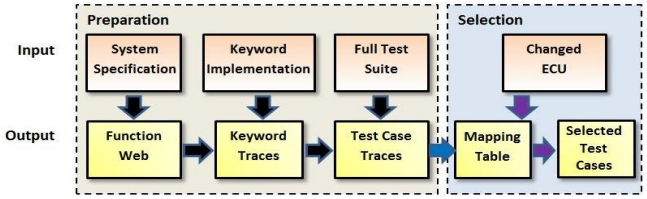

Fig. 7. Process Model for Trace-Based Test Selection [45].

Although several models are available that can manage software artefact traceability, most of them are restricted to a few artefact types. The model ATM [39] has considered requirement level artefacts, SPEQTRA [44] is based on test case artefacts, Trace++ [40] has addressed issues in the Agile-based development and other approaches have emphasized only on development level artefacts. A single model is not sufficiently addressed the traceability between heterogeneous artefacts in a CICD pipeline due to the inbuilt complexity; Thus, traceability management in a DevOps practice is still an active research area.

B. Related Studies on Traceability Management

Consistency management of a large set of artefact relationships, when a change occurs during the software development process is a costly task that consumes more time and effort. Although there are few studies on managing traceability in many artefacts, there are several studies that have focused on traceability maintenance of a small set of artefacts. It is important to ensure the correctness of traceability over time [26][23]. The proper identification of a feasible traceability management approach could minimize the associated cost and effort.

Traceability recovery management system incorporating IR techniques such as VSM and LSI were used in [46]. They have performed an incremental semi-automated traceability recovery by integrating into an artefact management tool called ADMS [47]. Moreover, they have identified quality issues in the textual descriptions of the traced artefacts using IR tools. However, their results have shown that IR techniques are not sufficient to identify all the traceability links and required to remove a large number of false-positives manually. An approach named SCOTCH+ (Source code and COncept based Test to Code traceability Hunter) was presented in [48] that has addressed the JUnit test to code traceability. The techniques; dynamic slicing and textual information analysis were used in this approach and have shown results with high accuracy.

The tool Software Artefact Traceability Analyser (SAT-Analyser) [21][48] has addressed the traceability among requirements artefact, UML class diagrams regarding the design artefact and the source code artefact in Java programming language. It has used NLP and traceability has been established based on a string similarity computation using the Jaro-Winkler algorithm and Levenshtein Distance algorithm along with WordNet synonyms and pre-defined dictionary ontology. Next, the artefacts and their established trace links were parsed through the Document Object Model (DOM) parser and converted into a predefined XML structure for traceability graph representation. However, this approach lacks the artefact support for the entire SDLC. Subsequently,

this work has extended to support DevOps based software development [49][50]. This approach manages the traceability among heterogeneous artefact types that are involved in a DevOps environment covering each stage in SDLC. Additionally, this work has addressed continuous changes using change detection, change impact analysis and change propagation. Further, this study has supported the collaborative nature in DevOps practice by integrating the SAT-Analyser tool with the existing project management tools.

Accordingly, these related studies have mainly considered the automation of traceability management. Requirement, design level artefact traceability and enhancing traceability with visualizations have been slight considerations. The interest in obtaining complete automation in literature is advantageous for DevOps in practice. But having traceability support for all artefact types in overall SDLC phases is also required along with automation to be applicable to DevOps which is not significantly addressed together in literature.

VI. Traceability Management Tools

Variety of traceability management tools is available in the literature. These tools can be classified as proprietary tools: commercial and open source and research-based prototypes. Additionally, these tools can be grouped as non-Graphical User Interface (GUI) supportive and tools with fine-tuned IDEs. Among them, only a few sets of tools support traceability management in a DevOps environment, that considers all the artefacts from the requirement phase to delivery and maintenance phases. The overall analysis of commercial tools is presented in Table III. Considering the proprietary tools, TraceMaintainer [15] is an independent tool that supports any Computer-Aided Software Engineering (CASE) tool by allowing to work in any heterogeneous environment. However, this tool is limited to the requirements and design artefacts.

The tool TraceME [48] is a freely available integrative tool within the Eclipse IDE as a plugin. Tools such as TIRT [34], are limited to specific application domains such as software product line-based information retrieval. The artefacts such as test scripts, configuration files, deployment and delivery related artefacts in a DevOps environment have not significantly addressed in these existing tools. Thus, there is a need for tools with CI features that have addressed all the artefact types and support the CICD process.

Accordingly, lack of tool support for all types of software artefacts in the DevOps practice with a minimum of dependencies, such as depending on a given IDE or a platform like Windows or Ubuntu is observable. Further, most of the tools lack proper visualization of traceability information. Only some tools are adapting the traceability graph visualization and still, those representations are not using colour codes or interactive usability attributes.

TABLE III. Traceability Management and Visualization Tools

Tool name	**Artefacts**	**Traceability technique**			**Visualization technique**				
		Rule-based	***Hypertext-based***	***Integrative***	***Traceability matrix***	***Cross-reference***	***Tree-map***	***Hierarchical tree***	***Traceability graph***
TraceMaintainer [15]	Requirements, structural UML	X		X				X	
TraceME [48]	All			X				X	X
Rational DOORS [51]	Requirements		X	X		X		X	
Rational RequisitePro [52]	Requirements			X	X		X	X	X
Cradle [53]	Requirements			X		X		X	
ReqView [54]	Requirements			X		X			X

VII. Quality Measures

One major hindrance in the practical application of traceability is the cost and resource consumption. In generic software development organizations are reluctant to spare the resources on traceability. Therefore, validating the traceability aspects and ensuring the quality measures are important to encourage real-world usage. Usability measures consider the user experience and interactivity based on evolving user expectations. The usefulness, ease of use, learnability and likeability are treated as the general concepts of the usability [55][56]. Generally, a larger user base is considered to measure the usability aspects of a traceability tool. Further, the degree of automatization by reducing human effort in trace link generation, time, user interface improvements with the aid of colour codes and help-tips are used as usability metrics [57].

The traceability coverage refers to the set of identified correct links after a traceability link recovery process. The link coverage analysis helps to identify the poorly traced artefacts. Traceability coverage can be defined as:

$$\text{Traceability Coverage} = \frac{|\text{links\_a (targets)}|}{|\text{targets}|} \quad (1)$$

where, *targets* is the set of target artefacts and *links_a (targets)* represents the set of links traced between the artefact *a* and the artefacts in the set *target* [4].

The statistical methods precision, recall and F-measure are widely used accuracy measures [39]. Precision refers to the number of correct instances among all the retrieved instances (2). Recall or the sensitivity denotes the number of correct ones among a total number of relevant instances (3) [58]. The higher precision saves time in locating and implementing the changes, while higher recall is useful in confirming that all proposed changes will be taken into consideration. Moreover, F-measure (F1 Score) is a measure of accuracy and defined as the weighted harmonic mean of the precision and recall of a test. This conveys the balance between the Precision and the Recall. F-measure assumes values to be in the interval [0,1].

$$\text{Precision} = \frac{|\text{relevant trace links} \cap \text{retrieved trace links}|}{|\text{retrieved trace links}|} \quad (2)$$

$$\text{Recall} = \frac{|\text{relevant trace links} \cap \text{retrieved trace links}|}{|\text{relevant trace links}|} \quad (3)$$

$$\text{F1 Score} = 2 * \frac{\text{Precision} * \text{Recall}}{\text{Precision} + \text{Recall}} \quad (4)$$

Ensuring reliability is important in traceability establishment and management. It ensures that a process will perform its intended tasks, without any failures for a given time. The Hidden Markov Chain is one of the algorithms that can be applied to measure software reliability. For instance, Lee et al., have proposed an approach using Markov Chain for measuring reliability in UML by supporting traceability to overcome the limitations in analysis and modelling [59]. Further, traceability matrix-based techniques help to preserve the reliability with respect to requirement artefacts.

Network analysis is originated from graph theory and applied on problems that are represented in a node-link structure as a graph. This technique is actively used for graph analysis in various domains such as food chains in ecosystems to internet traffic in computer systems. Network analysis comprises of several centrality measures that can be used to validate and assess the accuracy of the traceability links in networks [60]. Fig. 8 shows an example of four centrality measure values, degree centrality (D), closeness centrality (C), betweenness centrality (B), eigenvector centrality (E), obtained using the Python NetworkX libraries. The maximum and minimum centrality measures of nodes in a traceability graph is useful to identify the most and least connected artefact, centralized artefact, the artefacts with control over the network and influential artefacts. Further, these four centrality measures have used in validating traceability results [61].

Degree centrality (5) describes the status of a node in accordance with its adjacent links by counting the neighbouring nodes [60][62]. It has two versions as in-degree that counts incoming relationships and out-degree that counts a number of outgoing connections. Thus, a node that has a higher degree centrality value denotes that it is more central and has more power to be visible due to a maximum number of relationships in that network with respect to other nodes. For instance, nodes R and T have the maximum degree centrality in Fig. 8 with a value of 4 since they both have four connections.

$$C_{\text{Degree}}(v) = \deg(v) \quad \text{where, } v \text{ denotes a node.} \quad (5)$$

Closeness centrality (6) defines the nearest node to most nodes [60][62]. It considers the sum of a node to all the other nodes available in a network. Hence, a maximum closeness centrality value depicts that the distance from that node to the majority of other nodes in a lower value having the ability to send information fast. In Fig. 8, maximum closeness centrality value belongs to two nodes; R and T.

$$C(x) = \frac{N}{\sum_y d(x,y)} \quad (6)$$

where, *d(x,y)* denotes the distance between vertex *x* and vertex *y*. *N* denotes the number of nodes in the graph.

Betweenness centrality (7) denotes the occurrences of a node being a bridge along the shortest path to other nodes [60][62]. Here, it is assumed that information flow is performed over the shortest paths between nodes. Accordingly, a node with a higher betweenness centrality value may have control within the network in terms of data passing as in Fig. 8 the node T has the maximum betweenness centrality value.

$$g(v) = \sum_{s \neq v \neq t} \frac{\sigma_{st}(v)}{\sigma_{st}} \quad (7)$$

where, *v*, *s*, *t* denote nodes and $\sigma_{st}(v)$ is all the shortest paths between nodes *s* to *t* that pass through node *v*.

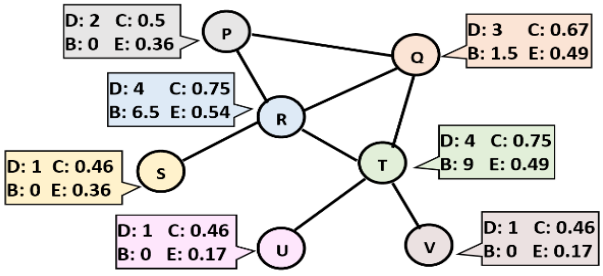

Fig. 8. Example of Network Centrality Measures.

Moreover, EigenVector Centrality (EVC) also named as eigen centrality defines the most influential nodes in terms of the connectivity of a node with the other well-connected nodes in a network [60][62]. EVC is the principal eigenvector of an adjacency matrix defining the network. If a node's EVC is a higher value, it shows that it is a more influential element in that network with respect to remaining nodes [61]. A node is influential, if it affects other highly influential nodes than the lesser nodes [63]. Thus, in EVC, nodes influence the linked nodes without being restricted to the shortest path or the adjacency of node connectivity [62]. For example, node R has the maximum EVC value in Fig. 8. Due to these factors, EVC measure is applied in Google web page ranking and to analyze the traceability establishment accuracy [62][63].

VIII. Discussion

One major challenge in tracing software artefacts is the heterogeneity due to different abstraction levels and the lack of defined data formats of the artefacts. Thus, it is essential to identify the key elements from a given artefact for proper relationship establishment. Although there are a variety of related studies, most of the literature has certain limitations such as being addressing only a few artefacts types, not addressing aspects related to software development in DevOps practice, lack of support towards CICD and lack automation [40][45]. Considering the tool support, many tools have traceability visualization and scalability issues leading to the inability to manage traceability with many artefacts.

Moreover, the need for techniques and tools to recover traceability links in legacy systems is particularly important for a variety of software evolution tasks such as transitioning from traditional software process models to DevOps. The tasks include general maintenance tasks, impact analysis, program comprehension and more encompassing tasks such as systematic reuse traceability types and reverse engineering for redevelopment [4]. Some existing studies have addressed these aspects separately such as change impact analysis rather than along with traceability [64][65]. Hence, overall there is a lack of traceability management support to cope with the continuous integrations in DevOps practice.

Traceability support in a DevOps based software development environment can be achieved by addressing the identified limitations. Several future possible research directions can be suggested based on this survey. The efficiency and effectiveness of the software artefact extraction process can be improved by exploring data pre-processing and information retrieval techniques that support heterogeneous artefact types, which can result in a more accurate traceability establishment process. Moreover, a generalized framework can be modelled to manage traceability, so that the automation can be achieved irrespective of the project domain and scale. Consequently, it is important to have a traceability representation with a scalable visualization technique that can lead to better decision making with minimum visual clutter. Additionally, traceability result validation is important to avoid inconsistencies among artefacts and reduce the associated cost due to re-work. Therefore, it is essential to determine a traceability methodology to synchronize software artefacts, such that the changes made to an artefact in any phase of the SDLC can preserve the consistency across all the artefacts. Furthermore, the traceability management process can be refined with automation and cutting-edge CI features including impact analysis and change propagation addressing the frequent artefact changes with a minimum cost.

IX. Conclusion

Software artefact traceability in DevOps practice is an evolving research area with the need for software evolution and maintenance. Software development in DevOps practice considers frequent software change requests and facilitates for continuous integration and continuous delivery process. This study addressed the applications of artefact traceability in a DevOps environment, which is challenging than managing traceability in a traditional software development process. We have identified the traceability concepts, terminologies, traceability models in DevOps practice, traceability establishment techniques, visualization approaches and traceability evaluation methods. Moreover, this study explored the related work on artefact traceability management and the existing traceability tool support. We have identified that there is a lack of traceability management features, which can be practically applicable in DevOps software development environments. This study has identified the requirement of having a generalized and automated traceability management solution that can handle any type of frequent artefact change in a scalable manner with a proper visualization approach.

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Blood Diseases Detection using Classical Machine Learning Algorithms

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***Abstract*—Blood analysis is an essential indicator for many diseases; it contains several parameters which are a sign for specific blood diseases. For predicting the disease according to the blood analysis, patterns that lead to identifying the disease precisely should be recognized. Machine learning is the field responsible for building models for predicting the output based on previous data. The accuracy of machine learning algorithms is based on the quality of collected data for the learning process; this research presents a novel benchmark data set that contains 668 records. The data set is collected and verified by expert physicians from highly trusted sources. Several classical machine learning algorithms are tested and achieved promising results.**

***Keywords*—Machine learning; classification algorithms; decision trees; KNN; k-means; blood disease**

I. Introduction

Blood has many secrets that affect human life. It is the postman that circulates through body and visits all organs [1]. The growth in age should be reflected in blood. This change could be detected by the values of parameters inside blood analysis tests [2]. Depending on several attributes like age, gender, symptoms, and any health conditions, the physician can choose the specific blood tests for diagnosing the disease. Many blood tests are standard and essential for everyone to get. Blood tests are widespread because of that; most physicians may recommend blood tests to predict the health level of the patient's body [3] [4].

Most of the blood tests do not need special conditions like fasting for 8 to 12 hours before the test or preventing some kinds of medicine [5]. By testing the fluid, different parameters in the blood van be measured. The results help to identify health problems in the early stages or nay predictable diseases [6]. Physicians cannot diagnose diseases and health problems with blood tests alone. However, they can use them as a factor to confirm a diagnosis. These factors may include some signs and symptoms, which could be integrated with other vital signs for diagnosing the diseases [7]. The disease is diagnosing, and prediction process is a necessary process which is based on the quality of data and physician's experience. Applying modern technological tools for helping physicians to improve the accuracy of disease diagnosing, become one of the hot topics of research, especially machine learning and artificial intelligence algorithms [8].

Machine learning is a data analysis technology that teaches computers to act like humans. It uses computational methods to extract information directly from data [8]. The performance of the machine learning algorithm is improved according to the quality of data, as well as enhancing the disease prediction process [9].

The main objective of this research is using machine learning techniques for detecting blood diseases according to the blood tests values; several techniques are performed for finding the most suitable algorithm that maximizes the prediction accuracy [9]. The rest of this paper is organized as follows. Section II introduces background information about the used techniques. Section III presents the different related methods on blood disease prediction using ML classifiers. Section IV describes the data set and the blood test attributes. Section V shows the experiments results. Finally, section VI presents the conclusion and future work of the research.

II. Background

Machine learning is a computer science branch that is responsible for the development of computer systems that can learn and change their reactions according to the situation [9]. The Machine Learning methodology is depending on learning from data inputs and evaluating the model results and trying to optimize the output [10]. It is also used in data analytics for making predictions on data. Figure 1 shows a brief of machine learning activity. Machine learning consists of 3 main models [11]:

- Supervised Learning: Computer is trained with presented inputs and their desired outputs, for predicting the output of future inputs.
- Unsupervised Learning: Computer is presented with inputs without desired outputs.
- Reinforcement learning: Computer interacts with the environment, and it must perform a specific goal without training.

Machine Learning techniques become an essential tool for prediction and decision-making in many disciplines [12]. The availability of clinical data leads machine learning to play a critical role in medical decision making. It serves as a valuable aid in identifying a disease for improving clinical decisions and choosing suitable medical procedures.

Fig. 1. MACHINE LEARNING ACTIVITIES [11].

We used the following classifiers for classifying the patients based on learning datasets; these classifiers are:

- Naive Bayes: it is based on the Bayes theorem. It considers that each attribute in unclassified tuple X is conditionally independent [13].

$$P(C_1|\boldsymbol{X}) = \prod_1^n P(X_i|C_1)P(C_1) \quad (1)$$

P(C1|X) is the probability of tuple X belongs to Class 1, P(C1) the probability of Class 1 that exists in the training set, and $\prod_1^n P(X_i|C_1)$ the production of each attribute in Tuple X the belongs to Class 1.The classification is done by calculating the probablility of tuple X for each labeled class , and the tuple will be classified to the class with the maximum probablility [13]. This algorithm needs a small amount of training data for estimating the vital parameters which made the algorithm extremely fast compared to more sophisticated methods.

- A Bayesian network: it is a probabilistic directed acyclic graphical model; (DAG) it represents a set of variables and their conditional relies on a directed acyclic graph. It is ideal for dealing with an event that occurred and predicting the likelihood that any one of several possible known causes [14].
- A multilayer perceptron: it is a feedforward neural network. It consists of three layers of nodes or more: an input layer, a hidden layer, and an output layer. Each node is a neuron that uses an activation function. It uses a backpropagation supervised learning technique for training; it can distinguish data that is not learned before [15].
- Logit Boost: it is one of the boosting algorithms; its primary purpose is predicting basic protein classes. It performs classification using regression as the base learner, which can deal with multi-class problems [16].
- Random forests classifier: it is a band learning method for classification that operates by constructing a multitude of decision trees by training records with their labeled classes. After building the tree, the unknown records could be classified [17].
- Support vector machine: it represents the training data as points in a flat separated space by an apparent gap. New examples are mapped into space with the forecast category based on which side of the gap they fall [18].
- K-Nearest Neighbor (KNN): it classifies the object based on the distance between the new object and the defined objects. The object is assigned to the class k that has the shortest distance to class k that defined as the nearest neighbor [19].
- Regression analysis: it is a process for rating the relationships among variables. It includes many techniques for modeling and analyzing several variables for finding the relationship between a dependent variable and one or more independent variables. After finding the relation, the missing values of the variable could be predicted with high accuracy [20].
- Decision Tree: it models the attributes and its values with decisions in the tree; where the nodes contain attributes with its values and leaves contain decisions. The algorithm considers all features and makes a binary split on them. It orders the attributes on the tree according to the information gain value in descending order. After building the tree, new tuples will be classified according to its values by traversing the tree until reaching the leaf that contains the class [21].

All these classifiers are used in the diseases prediction process for improving the clinical decision making and minimize the medical errors, in the next section, we listed the recent researches that using the machine learning in blood disease analysis.

III. RELATED WORK

There are many studies in the field of machine learning techniques in disease detection, but a few numbers of them interested in blood diseases detection. Gregor Gunčar [22] and other co-authors write one of the most recent researches that worked on blood disease detection by using machine learning techniques. They used machine learning algorithms based on blood test results. They have built two models to predict blood disease. The first one is a predictive model used most of blood test parameters, and the second one used only a reduced set that is most common inpatient admittance [22]. The two models achieved good results; they get 88% accuracy in the first model, 59% in the second. The key point of this study shows that a machine learning predictive model based on blood tests can predict haematologic accurately. This research contains some limitations; some parameters were not calculated like f-measures and recall that may lead to better results [22].

David Martinez [23] and other co-authors are also interested in blood disease detection, but they concentrate on the textual content of the clinical reports other than the values of blood analysis parameters.

They collected free-text computed tomography (CT) over a specific hospitalization period (2003–2011); this collection contains 264 Invasive fungal diseases (IFDs) and 289 control patients. They worked with text mining methods and on the

sentence level [23]. They tested a variety of Machine Learning, rule-based, and hybrid systems. Also, it extracts the bags of words, bags of phrases, and bags of concepts. The proposed model used Support Vector Machines and achieved a high recall and precision at 95% at 71% respectively. The core of this model is the high quality of the collected documents and the extraction of information from textual reports and uses them in the disease prediction [24].

IV. Blood Diseases Analysis Data Set

This research presents a new benchmark dataset; it contains 668 patient's blood analysis. Each blood analysis contains 28 parameters; these parameters are presented on table I.

The dataset contains four main classes related to four different blood diseases:

- **Thrombocytopenia**: it is about the lack of platelets. It is not so dangerous but sometimes leads to bleed too much [25].
- **Leukocytosis**: it causes an increase in white cells above the normal range in the blood. It may cause certain parasitic infections or bone tumors, as well as leukemia [26].
- **Anemia**: it **is** a decrease in the amount of hemoglobin or red blood cells in the blood. It may cause vague and may include feeling tired, shortness of breath, or weakness [27].
- **Normal**: in this class, which all parameters values are normal, and there are no essential notifications in the blood analysis.

TABLE. I. Blood Analysis Parameters [25]

Parameter	Description	Normal Range Values
Age	Age of patient	
Sex	Gender of patient	
WBC	white blood cells	normal 4.5-10
RBC	RED blood cells	for female 4.2 to 5.4
Hgb	Hemoglobin	Newborn Babies 17- 22
HCT	Hematocrit	For women: 36.1% to 44.3%
MCV	Macrocytic Anemia:	27 to 31
MCH	Mean Corpuscular Hemoglobin	30 and 37
MCHC	Mean Corpuscular Hemoglobin Concentration	33-36
PLT	Platelet Count	150,000 to 400,000
RDW-SD	Red blood cell distribution width	29-46
RDW-CV	Red blood cell distribution width	11.6 – 14.6%
PDW	platelet distribution width	
MPV	Mean platelet volume	7.5-11.5
P-LCR	Platelet larger cell ratio	
PCT	Procalcitonin	0.1-0.5
NEUT	Neutropenia	1500-8000
LYMPH	Lymphocytes	1000 to 4000
MONO	Mononucleosis	
EO	Eosinophil granulocyte	1 to 6
BASO	Basophil granulocyte	0.0 - 2.0 %
IG	Intravenous immunoglobulin	1-2 grams
NRBC	nucleated red blood cells	0
RET	Reticulocytes	0.5% to 2.5%
IRF	Immature reticulocyte fraction	0.8–4.7% of reticulocytes
LFR	low fluorescence ratio of reticulocytes	87.9–98.4%
MFR	medium fluorescence ratio of reticulocytes	1.6–11.0%
HFR	high fluorescence ratio of reticulocytes	0.0–1.7%

Each record in the proposed dataset is labeled with his related class; this classification is performed manually by expert physicians.

V. Experiments Results and Discussion

Using the Weka tool, a classical machine learning algorithms are applied on 668 records that belong to four different classes as described in the data set section. 10-fold cross-validation is used for all of the experiments after performing the required preprocessing modules presented in fig.1. Cross-Validation is a statistical method of evaluating and comparing learning classifiers by dividing data into two segments: one used to learn or train a model and the other used to validate the model. The training and validation sets must cross-over in successive rounds such that each data point has a chance of being validated against.

For each classifier several metrics were measured for determining the accuracy. Furthermore, the parameters values of each classifier were changed according to the specifications of each classifier. Table II presents the evaluation metrics used in the experiments and their description. Table III shows the experiments results. The accuracy of all classifiers is ranged between 71.2% and 98.16%. The LogitBoost classifier has the highest accuracy, where Support Vector Machine classifier has the lowest value. Table IV shows the classifiers accuracy in descending order. The overall results prove the success of applying the classical machine learning algorithms in the process of blood diseases prediction.

TABLE. II. Evaluation Metrics [28]

Metric	Description
TP Rate	True Positive Rate
FP Rate	False Positive Rate
Precision	A measure of statistical variability
Recall	Classifier Sensitivity
F-Measure	A measure of a test's accuracy
MCC	A measure of the quality of binary (two-class) classifications
ROC Area	A graph showing the performance of a classification model at all classification thresholds
PRC Area	Precision/Recall
Accuracy	Accuracy of classifier
Mean absolute error	Assessing the quality of a machine learning model

TABLE. III. Experiments Results

Classifier	TP Rate	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Accuracy	Mean absolute error
NaiveBayes	0.816	0.059	0.862	0.816	0.835	0.753	0.933	0.857	81.60%	0.09
Bayesian network	0.929	0.04	0.936	0.929	0.93	0.898	0.984	0.967	92.86%	0.0362
MultilayerPerceptron	0.918	0.04	0.918	0.918	0.918	0.879	0.974	0.95	91.80%	0.04
LogitBoost	0.982	0.01	0.982	0.982	0.98	0.972	0.995	0.987	98.16%	0.023
Random forests	0.971	0.022	0.971	0.971	0.969	0.956	0.996	0.99	97.12%	0.042
Support Vector Machine	0.712	0.329	0.799	0.712	0.64	0.494	0.691	0.584	71.20%	0.14
K-Nearest Neighbor	0.93	0.048	0.928	0.93	0.927	0.892	0.94	0.883	92.97%	0.04
Regression analysis	0.965	0.02	0.965	0.965	0.964	0.948	0.992	0.979	96.54%	0.0447
Decision Tree	0.97	0.018	0.969	0.97	0.969	0.955	0.979	0.955	97.00%	0.018

TABLE. IV. Accuracy Results in Descending Order

Classifier	Accuracy
LogitBoost	**98.16%**
Random forests	97.12%
Decision Tree	97.00%
Regression analysis	96.54%
K-Nearest Neighbor	92.97%
Bayesian network	92.86%
MultilayerPerceptron	91.80%
NaiveBayes	81.60%
Support Vector Machine	71.20%

VI. Conclusion and Future Work

Machine learning becomes an essential technique for modeling the human process in many disciplines, especially in the medical field, because of the high availability of data. One of the essential disease detectors is the blood analysis; as it contains many parameters with different values that indicates definite proof for the existence of the disease. The machine learning algorithm accuracy depends mainly on the quality of the dataset; for this reason, a high-quality dataset is collected and verified from expert physicians. This dataset is used for training the classifiers for obtaining high accuracy. We tested several classifiers and achieved accuracy up to 98.16% which realize the research objective, which is helping the physicians to predict the blood diseases according to general blood test.

The future work will focus on testing the proposed data set using different deep learning algorithms to compare between classical and deep learning approaches in this research area. Furthermore, an online Internet of Things (IOT) application will be implemented to collect and test more blood data.

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A Mobile Robot Teleoperation System with a Wireless Communication Infrastructure using a Leaky Coaxial Cable based on TCP/IP

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***Abstract*—In this study, we propose and develop a wireless teleoperation system for mobile robots using a leaky coaxial cable (LCX) with a wireless communication infrastructure. In closed spaces resulting from disasters, some problems have been reported, such as cable entanglement, disconnection of wired communications, and problems with teleoperations (e.g., unstable communication quality for wireless communications). In this paper, we propose a communication infrastructure system for teleoperation of a mobile robot using LCXs as a communication infrastructure that considers the above issues. In addition, the communication quality was measured for the operability of the mobile robot by constructing an IEEE 802.11b/g/n network using an LCX, and the effectiveness of the proposed system in an actual environment was confirmed. In the evaluation of the communication quality, bandwidth compression throughput values and packet jitter were measured as evaluation items at the packet level to objectively consider the teleoperation controllability.**

Keywords*—Mobile robot; teleoperation; leaky coaxial cable; teleoperation infrastructure

I. INTRODUCTION

After a disaster occurs, disaster reduction activities that minimize damage in the disaster-stricken area are important for early recovery and reconstruction activities [1]. In the Great Hanshin-Awaji Earthquake, survivors buried in the rubble had a survival rate of less than 5% after 72 h [2-3]. In order to carry out rescue activities quickly and effectively, it was necessary to perform disaster mitigation activities. Disaster mitigation is a method to minimize damage after a disaster occurs [4]. It is important to collect information on the disaster-stricken area during these disaster mitigation activities, where drones and already existing communication infrastructures are often used. However, in closed spaces, it is impossible to collect information from the sky, and the risk of failure of the already existing infrastructure is high. Therefore, these methods are difficult to use. In addition, information gathering by rescue workers is known to create a high risk of secondary disasters, such as fires and collapses, in closed spaces [5].

Therefore, considering these problems, various methods used to gather information via multirobot systems have been studied to reduce the secondary disaster risk caused by rescue workers.

The communication methods used by mobile robots include wired communication and wireless communication. The teleoperator of a mobile robot needs to use different communication methods according to the situation in the disaster-stricken area. Wired communication provides high-quality communication between the teleoperator and the mobile robot because this method has the advantage of being able to supply power from a cable. However, when operating a multirobot, there are physical limitations, such as the entanglement of the cables of the mobile robot. Therefore, in multirobot operations involving wired communication, one problem is the depression of the running performance of the multirobot and the disruption of communication owing to cable disconnection.

However, communication using radio waves can achieve teleoperations while maintaining the running performance of the mobile robot. However, when the mobile robot moves behind a wall or an obstacle, radio waves can get blocked; hence, increasing the risk of disconnection between the teleoperator and the mobile robot [6]. Additionally, radio waves are prone to attenuation; thus, the teleoperation range of mobile robots is smaller for wireless communication compared to wired communication. When the tele-operator controls a mobile robot, it is important to determine the best teleoperation method needed according to the environment of the disaster-stricken area; however, it is difficult to predict the situation of a disaster-stricken area in advance. Therefore, it is important to discuss various teleoperation methods that can be used in disaster-stricken areas.

We discussed using multirobot teleoperation systems in closed spaces that use leaked radio waves from leaky coaxial cables (LCXs) [7]. The purpose of this study was to develop a teleoperation method that is resistant to cable cutting and entanglement using an LCX while maintaining the mobile performance of the mobile robot. This is a new teleoperation method developed for closed disaster-stricken spaces, and it can promote disaster reduction activities from the viewpoint of diversification of teleoperation methods. However, teleoperation studies that involve LCXs have not yet defined the standardized operation method for mobile robots. In this paper, we propose a teleoperation method for a mobile robot

that uses LCXs with TCP/IP, and we evaluate the operability of the teleoperation of the mobile robot at the TCP/IP level.

In Section II, we have presented the problems which Wireless Teleoperation of a Mobile Robot in Closed Disaster-Stricken Spaces. Section III describes mobile robot system using an LCX as the communication infrastructure. Section IV describes throughput and packet jitter measurement methods to verify the teleoperation performance of the LCX. Section V has evaluated our proposed method which is maintaining the controllability of the mobile robot teleoperation using a TCP/IP-Compliant LCX network. Sections VI and VII has the discussion and conclusion.

II. Wireless Teleoperation of a Mobile Robot in Closed Disaster-Stricken Spaces

A. Wireless Teleoperation using ad hoc Networks

Many wireless teleoperation systems for mobile robots are based on TCP/IP protocols. The Robot Wireless Sensor Network (RWSN) is one method that involves the teleoperation of mobile robots using wireless communication [8-20]. RWSN is a system that provides information on a disaster, which can expand the communication distance between remote operators and mobile robots. In this system, while the mobile robot moves in the disaster-stricken area, the sensor node (SN), which is a small wireless computer, is deployed on the movement route to expand the wireless teleoperation range (Fig. 1). Then, most of the communication between the remote operator and the mobile robot conforms to TCP/IP protocols, in which the teleoperation is realized via packet communication. TCP/IP is highly compatible with the communication of the mobile robot because most of the control system of a mobile robot involves a PC. Therefore, socket communication is often adopted for mobile robot communication, and information communication by packet transmission and reception is typical. Therefore, in our system, we adopted a wireless LAN as the communication method.

After SNs are deployed, a wireless connection is made at each SN to construct a bead-like wireless ad hoc network. Using the RWSN, the remote operator can transmit while relaying instructions to the mobile robot. Therefore, the remote operator can gather information using the mobile robot while expanding the operational range. Moreover, in the RWSN, each SN can share the acquired information, and it is easy to expand and repair the network using a mobile robot. Therefore, this system is effective for collecting information in places where it is difficult to build a communication infrastructure and in disaster-stricken areas where there is a high risk of communication infrastructure disruption. However, in a beaded wireless ad hoc network, the problem is that the transmission speed decreases as the number of relays increases. Therefore, teleoperation of a mobile robot using an ad hoc network is difficult to operate in an environment with many corners that require many relays.

Additionally, network disconnection owing to the physical failure of the SN can make it difficult for the mobile robot to return.

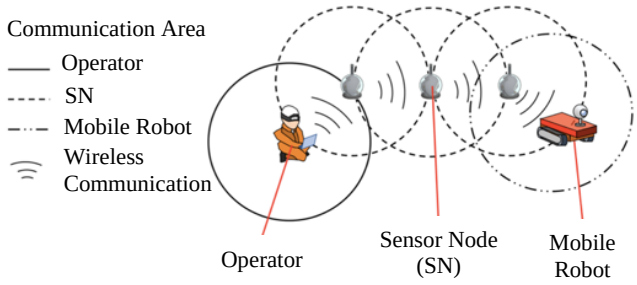


Fig. 1. RWSN.

B. Considerations for Wireless Teleoperation of a Mobile Robot

If the communication quality of the communication path is poor, the mobile robot may be disconnected from the network. Additionally, when the communication quality becomes unstable, the sensing information collected by the mobile robot cannot be transmitted to the remote operator; thus, the risk to the operability of the teleoperation is increased.

Thus, the communication infrastructure used for a new mobile robot teleoperation method requires a communication standard that provides easy monitoring of the communication quality and stable control. Additionally, when constructing a multirobot environment using the RWSN, routing becomes complicated, the number of relays increases, and it becomes difficult to maintain the transmission speed required for the operation of a mobile robot. Therefore, it is difficult to use the RWSN to gather information using a multirobot system. Regarding the movement distance, if the distance is extended too much, there will be a risk that the mobile robot will not be able to return if the relay is damaged. Considering utilization in affected areas, the fault tolerance of the communication equipment should be discussed as well as the distance extension. Therefore, for remotely controlling a mobile robot in an enclosed space in a disaster-stricken area, it is important to propose a new method that considers the following points.

- Adopting a wireless communication method that is capable of implementing a TCP/IP protocol.
- Communication quality maintenance in a multirobot environment.
- Teleoperation in large spaces.
- Network construction using communication equipment that is resistant to physical damage.

In the next section, we will consider a wireless teleoperation method for a mobile robot using an LCX, which considers the above points.

III. Mobile Robot System using an LCX as the Communication Infrastructure

A. Teleoperation System using an LCX

As mentioned in Section II, in order to develop a new teleoperation system for a mobile robot for use in a damaged closed space, it is necessary to consider the problems of the RWSN. In the previous section, we clarified the issues that

need to be considered and the requirements for the teleoperation of mobile robots in a closed space. Taking these into consideration, we have developed a wireless teleoperation method for mobile robots using an LCX. Because LCXs enable long-distance communication and network construction while maintaining high-quality communication, teleoperation can be performed while maintaining the traveling performance and communication quality of the mobile robot. Furthermore, LCXs create a wireless network around the cable by leaking radio waves from the cable. Moreover, when the LCXs are physically disconnected, communication up to the disconnection point is possible, and the specification for physical failure is strong.

Therefore, it is possible to construct a multirobot environment that is wirelessly connected using a single wired communication cable. However, LCXs have not been studied for teleoperation based on TCP/IP for mobile robots. In this paper, we propose a communication infrastructure that uses an LCX for TCP/IP as a mobile robot teleoperation system. Moreover, we evaluate the communication quality between the mobile robot and the remote operator at the packet level and discuss the teleoperation of the mobile robot on the basis of these results.

B. Communication Characteristics of the LCX

LCXs (Fig. 2(a)) have been studied and developed for fire radio and radio broadcasting in closed spaces, such as tunnels and subways. LCX is a cable designed to periodically make holes called “SLITS” in the outer conductor of a coaxial cable and leak part of the electrical signal from the “SLITS” to the outside (Fig. 2(b)). Information transmitted by the remote operator to the mobile robot is transmitted around the LCX by leaking radio waves from the SLITS. When the LCX is connected to an access point, the entire cable can be used as one antenna. The communication environment can be expanded in a wide area along the cable by laying the LCX, and a multirobot environment can be constructed. Even if the LCX is disconnected at some location along the path, it is possible to construct a network between the access point and its broken part.

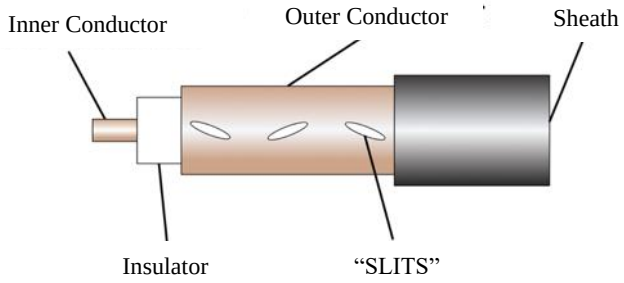
Fig. 3 shows a system for gathering information from a disaster-stricken area using multi-robots with an LCX as a wireless communication infrastructure. This system assumes use in closed spaces after a disaster. In this system, after a disaster occurs, a cable-laying robot equipped with an LCX uses the radio waves leaked from the LCX and lays out the LCX while advancing in the closed space. After the LCX is laid out, the mobile robot becomes able to perform long-distance communication without physical restriction from the wired cable using the radio waves leaked from the LCX.

C. Communication Infrastructure for Teleoperation using LCX Networks with TCP/IP Protocols

The communication method used in our proposed system included a wireless LAN from the IEEE 802.11 series. Currently, general-purpose PCs are generally used as the control systems for mobile robots. Moreover, communication between general-purpose PCs is highly compatible with TCP/IP for performing flexible network construction. Therefore, in addition to the possibility of packet communication, communication between the remote operator and the mobile robot needs to adopt a communication standard that can work with the control system of the mobile robot.

Thus, for this system, we decided to use the IEEE 802.11 series as the communication protocol. Then, we adopted IEEE 802.11g for network connection between the LCX and the mobile robot. Throughput, which is the information transmission rate of IEEE 802.11g, has a theoretical value of 54.0 Mbps. Nitta et al. studied the wireless teleoperation of heavy-equipment robots while streaming camera images and reported that teleoperation is possible if the throughput value is 4.0 Mbps or more [8]. Additionally, in our proposed system, teleoperation is possible if the communication speed between the remote operator and the mobile robot is 4.0 Mbps or more, and IEEE 802.11g meets this requirement. In addition, teleoperation of multi-robots using an LCX as a communication infrastructure is required to maintain a certain operation performance level by the packet control.

(a) Picture of an LCX



(b) Internal structure of the cable

Fig. 2. LCX.

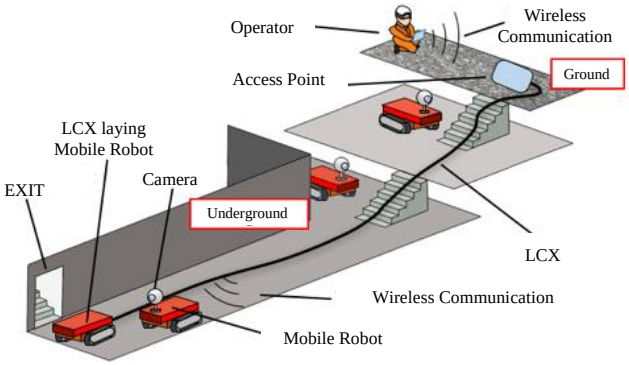


Fig. 3. Teleoperation System of a Mobile Robot using an LCX.

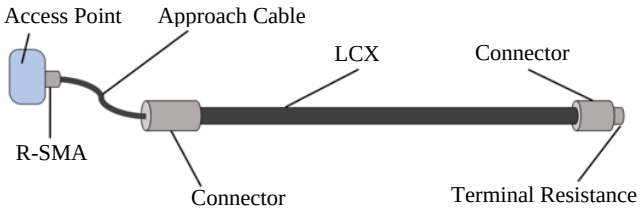


Fig. 4. An LCX Connected to an Access Point Capable of TCP/IP-Compliant Network Construction.

Therefore, we decided to use UDP communication without confirming the connection response request as the communication standard for packet communication between the multirobot and the operator. In our network construction based on TCP/IP, we used an access point with an SMA terminal that can connect to the LCX (Fig. 4).

In the next section, communication quality properties that need to be evaluated between the mobile robot and the remote operator will be defined, and the methods for measuring them will be described. In addition, we built a TCP/IP-compliant network using an LCX, and we will discuss the evaluation of the communication quality at the packet level.

IV. Throughput and Packet Jitter Measurement Methods to Verify the Teleoperation Performance of the LCX

A. Evaluation of the Transmission Speed

Remote operators can operate by receiving images and sensor information acquired by a mobile robot. However, because the amount of information fluctuates, it is necessary to monitor the communication quality to maintain a stable operation. Therefore, it is necessary to determine the transmission speed between the operator and the mobile robot during teleoperation. The transmission speed on the TCP/IP-compliant communication path was evaluated as the throughput at the packet level. Throughput [bps] indicates the amount of transmission per second received by the receiving computer (Fig. 5).

Additionally, bandwidth compression throughput represents the maximum receivable number per second by transmitting a large number of packets from the transmitting side. It is assumed that a large amount of information will be transmitted for the information acquired by the mobile robot in a disaster-stricken area, such as three-dimensional space information, moving image information, and different types of sensing information. Therefore, for the teleoperation of a mobile robot via an LCX, we used a band compression throughput measurement that can determine the upper limit of the transmission speed. Additionally, in our system, to measure the accurate upper limit of the throughput, we sent as many packets as the computer could process. The packet size of the transmission packet was set to 1,400 bytes, which is the upper limit. In this system, the bandwidth compression throughput was calculated assuming that the packet size is B [byte], the total number of received packets is n, and the time required to complete the measurement is t [s]. Then, the band compression throughput, Th [bps], can be expressed by the following equation:

$$Th = \frac{8Bn}{t} \quad (1)$$

The reduction in the upper limit of throughput delays the transmission and reception of sensing information and deteriorates the operability of a mobile robot. Therefore, it is important to monitor the bandwidth compression throughput when the mobile robot is remotely operated. Therefore, we developed an application for evaluating the bandwidth compression throughput and implemented it on the mobile robot and the teleoperation computer.

B. Evaluation of Packet Fitter

A remote operator sends command packets to teleoperate a mobile robot. In order to maintain the operability of the mobile robot, it is necessary to send and receive command packets at fixed time intervals. Disturbances in the transmission and reception interval of the command packets reduce operability because they interfere with teleoperations. Therefore, it is necessary to monitor the transmitted and received intervals to maintain operability. Therefore, in our proposed system, we evaluated the packet jitter to monitor the transmission and reception intervals of the command packets. Packet jitter is a disturbance in the arrival interval of packets. Assuming (1) e packet transmission interval is T ms and the deviation of the reception interval is d ms, the reception fluctuation is $T + d$ ms. A schematic of packet jitter is shown in Fig. 6.

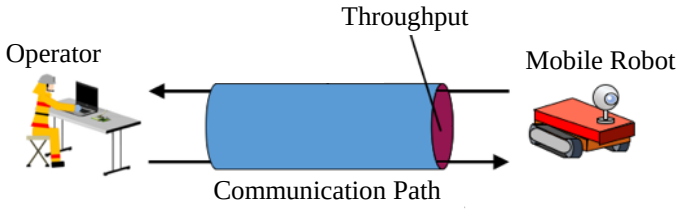


Fig. 5. Throughput [bps], the Amount of Information Transmitted Per unit Time.

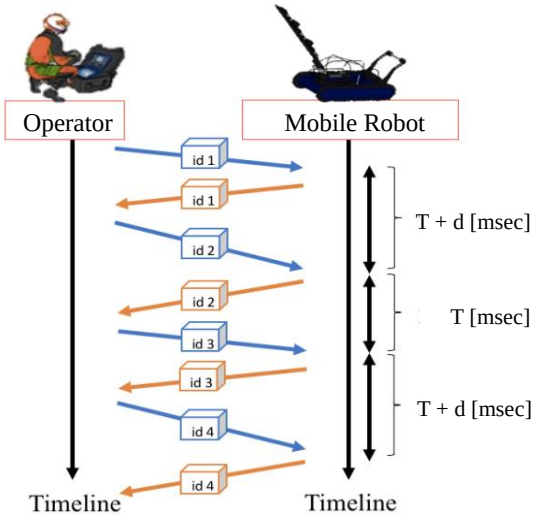


Fig. 6. Packet Jitter [ms], Fluctuations in the Packet Arrival Time.

Disturbances in the packet arrival intervals affect real-time applications. In VoIP and video streaming, disturbances in the packet arrival interval cause interruptions in the audio and the deterioration of the smoothness of the video. Even in the teleoperation of mobile robots, it is important to consider packet jitter because it is the same real-time system as these applications. In our proposed system, the command packet transmission interval was set to the same 20 ms interval as in real-time applications, such as VoIP and Skype. Remote operations are not affected when the packet reception range is 19–21 ms. However, arrival of packets outside this range must be monitored because of the problems mentioned above. Therefore, we developed an application for packet jitter evaluation and implemented it on a mobile robot and a teleoperation computer.

In the next section, we will discuss the operability of teleoperation of a mobile robot using a network constructed using an LCX with TCP/IP. In our evaluation experiment, we constructed the network in a real environment and evaluated the band compression throughput and packet jitter to determine the operability of the teleoperation of the mobile robot when using an LCX and determined the effectiveness at the packet level.

V. Controllability of the Mobile Robot Teleoperation using a TCP/IP-Compliant LCX Network

A. Evaluation of Teleoperation Ability

In this experiment, an LCX was laid in a straight line and a wireless LAN environment was built around the LCX. Then, a computer for teleoperation and a mobile robot were wirelessly connected to the network built by the LCX, and the mobile robot was moved away from the operator to measure the communication quality. In this experiment, bandwidth compression throughput and packet jitter were measured as indices to evaluate the operability of the teleoperation. The mobile robot received a command packet containing movement information from the operator and was set to move according to the information in the command packet. In order to evaluate the bandwidth compression throughput, the number of packets used for transmission and reception was set to 10,000 to provide an accurate evaluation. In addition, for the evaluation of packet jitter, we transmitted 500 (packet size: 200 bytes) packets, taking into consideration the influence of various noises from the experimental environment.

B. LCX Network Connection Configuration

Fig. 7 shows the network configuration for this experiment. The TCP/IP-compliant access point was wired to the LCX, and a wireless LAN environment (IEEE 802.11g) was constructed around the LCX. The laying range of the LCX was a straight line of 100 m, and the wireless LAN network was developed in that range. For communication between the mobile robot and the remote operator, UDP was adopted by considering teleoperation, which is a real-time application.

The computer used for the teleoperation and the mobile robot were set to a static IP address to use this system in a multirobot environment. The network configuration shown in Fig. 3 looks like a bus-type topology, but this network topology was set up with a star-type topology for an easy-to-connect setup.

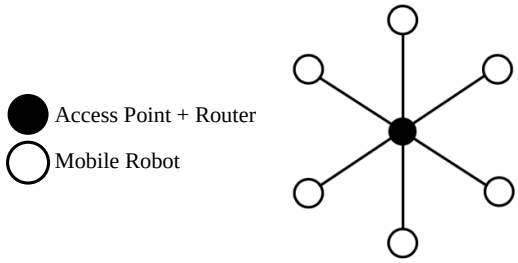


Fig. 7. Wireless Network and Mobile Robot Network Topology Constructed using an LCX (in the Experiment, only one Mobile Robot was Connected).

C. Network Construction Area Constructed by an LCX

In the teleoperation of mobile robots, it is necessary to determine in advance the construction range of the network used as the wireless communication infrastructure. The network construction area using an LCX as the communication infrastructure is the surrounding environment of the LCX in which the LCX is placed. However, for the teleoperation of our mobile robot, an area with a throughput of 4.0 Mbps or more was used as the network construction area, and it was necessary to evaluate it at the packet level.

For the throughput measurement, the bandwidth was compressed by transmitting a large number of packets on the communication path, and the calculation was performed by counting the number of packets that could be transmitted and received per unit time. This was measured by connecting a remote operator terminal to an access point that constructed a wireless LAN using a wire and by measuring the throughput between the LCX and a computer terminal that was connected wirelessly. For evaluation, a 100 m LCX was wired to the access point, laid in a straight line. The measurement was performed by moving the computer terminal in increments of 10 m, and the measurement was performed five times to obtain an average value. The computer terminal was placed at a distance of 0.3 m vertically from the LCX.

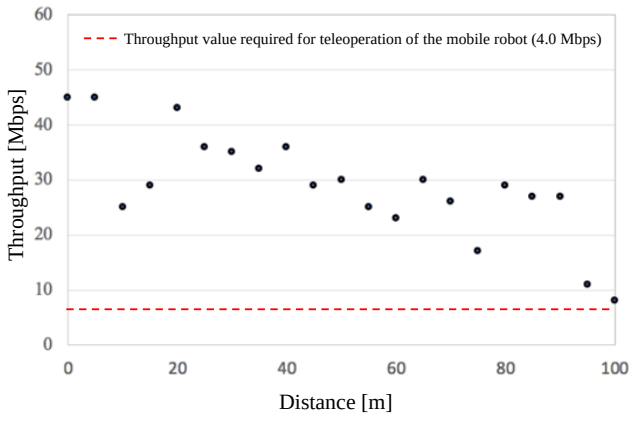


Fig. 8. Evaluation Results of the Network Construction Range of the LCX as a Function of the Throughput.

Evaluation experiments were conducted in an environment where no other wireless LANs existed. The network construction area when using the LCX was evaluated by the throughput measurement shown in Fig. 8. In this experiment, it was confirmed that the network constructed by the LCX used in the evaluation experiment for the proposed method could obtain a throughput value of 4.0 Mbps or more in the entire range. Throughput values tend to decrease as the distance from the Access Point increases; however, this is due to attenuation because of the cable length and is a normal result.

D. Movement of the Mobile Robot during a Communication Quality Measurement

The mobile robot moved remotely from the access point installation side (0 m) to the end point of the LCX (100 m) (Fig. 9). The movement path of the mobile robot was set 0.3 m away from the LCX in the vertical direction and parallel to the LCX. This experiment was conducted on a straight path of 100 m where no other wireless LAN environments existed (Fig. 10). Throughput and packet jitter were obtained by stopping the mobile robot at intervals of 5 m from 0 m to 100 m and by measuring five times to obtain the average value. Additionally, during the measurement of the communication quality, all communications related to teleoperation were stopped to provide an accurate result.

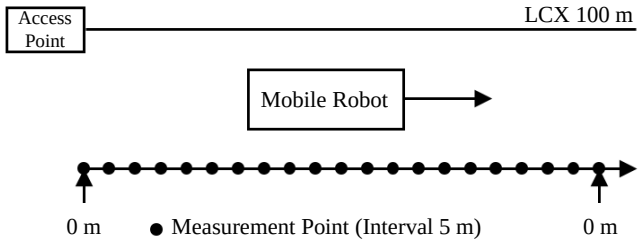


Fig. 9. Measurement Points of Communication Quality.

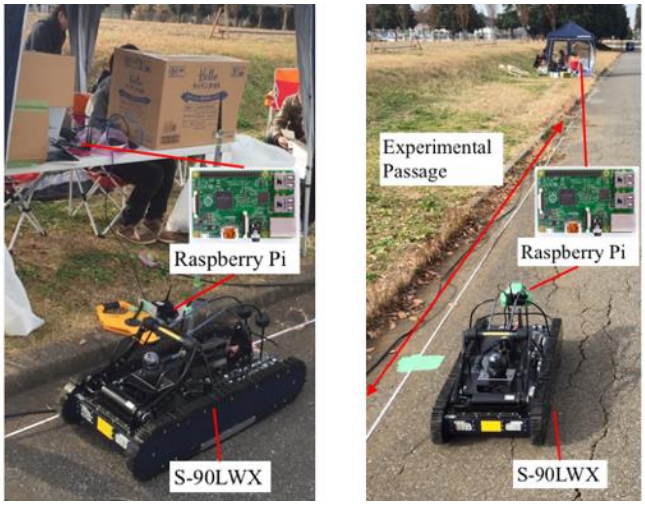


Fig. 10. Experimental Environment.

E. Equipment used for Teleoperation Experiments of the Mobile Robot

Raspberry Pi 2 (Model B) was used for the teleoperation computer and for the control system on the mobile robot. The LCX cable adopted was an LCXF-8D-LCX (HC Networks, Ltd., Tokyo, Japan), and the wireless access point used was AP-214 (Aruba Networks, Ltd., Santa Clara, CA, USA). For the mobile robot, S-90LWX (Topy Industries, Ltd., Tokyo, Japan) equipped with a crawler for the drive system was used as the rescue robot. We used the same Raspberry Pi 2 (Model B) as the remote control computer for the control system of the mobile robot, and adopted IEEE 802.11g for the communication system.

F. Results of Throughput and Packet Jitter in the Teleoperation Experiment of the Mobile Robot using the LCX Network

Fig. 11 shows the results of the evaluation of the throughput. According to our results, the mobile robot was able to move up to 100 m. The throughput value was maintained at 4.0 Mbps or higher, which is required for the teleoperation of the mobile robot, in the interval of 0–95 m. The average result at all measurement points was 25.7 Mbps, which was a value that would not affect the remote control of the mobile robot. However, the throughput value at 10 m was 33.3 Mbps lower than the value at 5 m. The result at 75 m was 17.4 Mbps lower than that at 70 m. The results for the 100 m point could not be measured because the network connection was disrupted. However, because the mobile robot was able to move up to 100 m, the communication quality was maintained just before the 100 m point.

Fig. 12 shows the results of the evaluation of packet jitter. We evaluated the proportion of the number of packets with a packet arrival interval of 19–21 ms. The results show that the ratio of the number of packets for the packet arrival interval of 19–21 ms was over 70% in the 0–95 m section, and the operability of the teleoperation did not decrease. However, the evaluation results at 100 m could not be obtained owing to network disconnection.

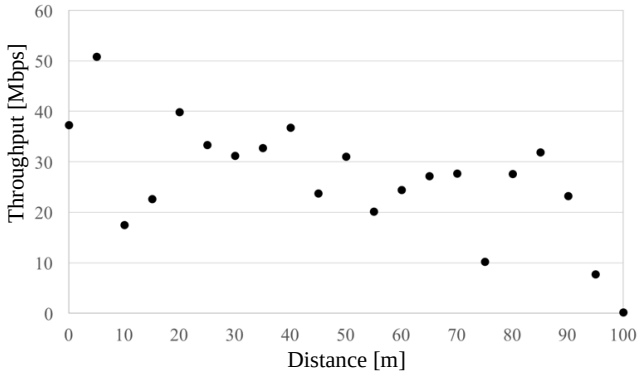


Fig. 11. Results of the Throughput Measurement.

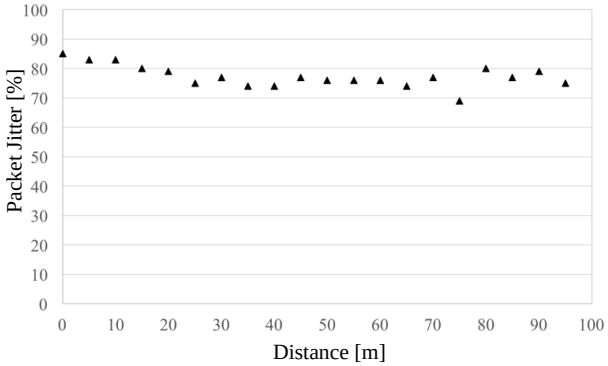


Fig. 12. Results of the Packet Jitter Measurement.

From these results, we confirmed that the teleoperation of a mobile robot using a TCP/IP-compliant LCX network can be performed without operability degradation or failure of real-time applications.

VI. Discussion

For evaluating the communication quality of the LCX network, throughput and packet jitter were measured in the range of 0–95 m. In addition, it was confirmed from the evaluation results that the values required for teleoperation can be obtained at all the measurement points except for the 100 m point. Therefore, the teleoperation range of the mobile robot can be constructed within the range of 0–95 m. The throughput decreased by 10.0 Mbps or more at measurement points of 10, 45, 55, and 75 m compared to that at measurement points immediately prior to these. The result was higher than 4.0 Mbps and did not affect the teleoperation of the mobile robot. At the next measurement point following the decreased measurement point, the throughput increased and recovered. The reason for these fluctuations may be a decrease in throughput due to environmental noises at the measurement point. Additionally, at the 95 m measurement point, the value was less than 10.0 Mbps and could not be measured at 100 m. The radio waves of LCXs have directivity on the access point side as shown in Fig. 13 and disconnection of the communication at the 100 m point may have occurred because the antenna of the mobile robot was out of the network.

For the packet jitter result, a packet reception rate of 70% or higher was observed except at the 75 m measurement point. At 75 m, the measured throughput also significantly decreased. This may have been due to environmental noises; however, because the reception rate was 69%, teleoperation was possible. At the next 80 m measurement point, the packet jitter became 80% and recovered.

This stability in the communication quality is a feature of communication using an LCX and is difficult to realize by a radio relay system, such as an RWSN. It is effective for use as an infrastructure for teleoperation in a disaster-stricken area where there is a high possibility of local environmental noise. In addition, there was no network disconnection or inoperable state between the operator and the mobile robot at 0–95 m of teleoperation.

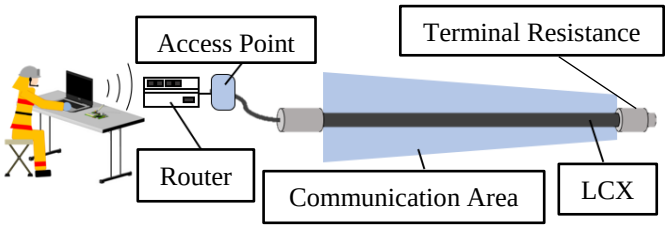


Fig. 13. Wireless Communication Area of the LCX because there was Directivity on the Access Point side, the Communication Range became Narrower as it Got Closer to the Terminal Resistance Side.

VII. Conclusion

In this paper, we proposed a new teleoperation system that implements TCP/IP on an LCX as a teleoperation method for mobile robots in a closed space. The LCX can construct a wireless network around the cable by emitting radio waves from the cable. By implementing TCP/IP on an LCX, and can effectively operate a mobile robot. Wired and wireless communication systems have been used to operate mobile robots in closed disaster-stricken spaces. However, physical disconnection and entanglement of cables and destabilization of communication quality in wireless communications are issues that hinder multirobot system deployment in closed spaces. The proposed system uses only one cable in a multirobot system; thus, the risk of physical disconnection and tangling is reduced. Moreover, in this system, the evaluation experiment confirmed that it is possible to maintain the communication quality between the mobile robot and the remote operator by combining wired communication with wireless communication. We adopted TCP/IP, which is widely used for robot communication as a communication standard, and it is a specification that can be implemented on many mobile robots. In our evaluation experiment, the effectiveness of the proposed method was confirmed using a mobile robot, and the operator was able to operate it without any operability issues during the experiment. Therefore, this proposed system can be effective as a new teleoperation method for mobile robot use in closed spaces after disasters.

This system is effective for multirobot system operations; however, in the future, we will implement the Resource Reservation Protocol for communication bandwidth compression of LCXs for effective operation in disaster-stricken areas.

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Communication Disconnection Prevention System by Bandwidth Depression-Type Traffic Measurement in a Multi-Robot Environment using an LCX Network

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***Abstract*—In this paper, we propose and develop a method for determining the transmission amount of each mobile robot connected to a network constructed with a leaky coaxial cable (LCX) by using broadcast packets. Tele-operation of mobile robots using an LCX network is more effective as an information collection method in closed spaces compared with existing methods in terms of the maintenance of the mobile robots' running performance and the stability of the communication quality for disaster reduction activity. However, when the transmission and reception of information exceeds the maximum transmission amount, communication disconnection and transmission amount reduction occur because of band division in the communication path, and there is a risk that mobile robots will be separated from the LCX network. Therefore, to prevent the network division and the decrease of transmission amount during multi-robot operation on an LCX network, we propose a method for determining the transmission amount of each mobile robot using broadcast packets. The proposed method is evaluated on an LCX network, and its effectiveness is confirmed by evaluating the transmittability of broadcast packets and operability of mobile robot.**

Keywords*—Multi-robot; tele-operation; leaky coaxial cable; LCX networks; operability; broadcast packets; transmittability of broadcast packets; network disconnection prevention; disaster reduction activity

I. INTRODUCTION

After a disaster occurs, disaster reduction activities are conducted to minimize damages, injuries, and fatalities. The investigation of the Hanshin-Awaji Earthquake indicated that survivors buried in the rubble had a survival rate of less than 5% after 72 hours. Therefore, the prompt implementation of disaster reduction activities is required to save lives [1-2]. To carry out effective disaster reduction activities, it is necessary to quickly gather information about the affected area for disaster deduction activities [3-4]. Drones and existing sensor systems are often used to gather disaster information. However, in closed spaces such as underground facilities and factories, it is impossible to gather information using drones, and there is a high risk that the existing infrastructure is disconnected from the outside [5-6]. In these situations, information must be collected by rescue teams, but there may be risks of secondary disasters such as fire and collapse. Therefore, a rapid information-gathering system using multiple robots is considered. In a multi-robot system, it is necessary to choose communication methods to use between robots and between robots and operators according to the operation environment.

Wired communication and wireless communication can be selected for the communication of mobile robots operating in the disaster area according to the environmental conditions. Wired communication is excellent for maintaining the communication quality between the remote operator and the mobile robot, but in a multi-robot environment, there is a high risk that cable tangle and disconnection may cause communication failure. Although wireless communication improves the running performance of a mobile robot, it is difficult to maintain the communication quality between the operator and the mobile robot because of the influence of structures and obstacles. Therefore, the wireless tele-operation range of the mobile robot is smaller than that of wired communication.

When tele-operation of a mobile robot is required, the communication method that matches the disaster area must be determined, but it is difficult to estimate the situation in the disaster area in advance. Hence, it is important to carry out various studies on tele-operation methods that can be used in closed spaces for effective disaster mitigation activities. It is important to be able to operate all the robots in a multi-robot system without entanglement or damage of cable to collect information quickly in a closed space affected by a disaster.

In this paper, we first discuss the construction method of a multi-robot environment using a leaky coaxial cable (LCX) network, considering the advantages and disadvantages of wired and wireless communication in the tele-operation of mobile robots. Then, we propose a communication disconnection prevention system to address the communication disconnection problem in the multi-robot environment and confirm the system's effectiveness by conducting evaluation experiments in a real environment. In the experiment, we evaluated the proposed method using a mobile robot, and considered the practicality in the real environment such as the afflicted area. The LCX network was also constructed in a real environment and used to evaluate the proposed method.

II. Construction of a Multi-Robot Environment using an LCX Network

A. Tele-Operation of a Mobile Robot using an Ad-hoc Network

Many studies on the wireless tele-operation of mobile robots in closed spaces have used the Robot Wireless Sensor Network (RWSN) system, which uses an ad-hoc network as a communication method [7-23]. RWSN is a system in which the mobile robot extends the tele-operation area by deploying a wireless communication repeater on a moving route (Fig. 1). However, when the number of relays on the communication path increases, the throughput value between the operator and the mobile robot decreases. The decrease of the throughput value not only reduces the operability but also increases the communication disconnection risk. Therefore, the operator must constantly monitor the communication quality with the mobile robot. In addition, in a multi-robot environment constructed using RWSN, the routing becomes complicated, so the number of relays is likely to change, thus causing the throughput to change. The fluctuation of the throughput leads to the disconnection of communication; thus, multi-robot operation using RWSN is difficult. In this study, to overcome the shortcomings of RWSN, we develop a tele-operation system for mobile robots using an LCX network as the communication infrastructure for the purpose of effective information-gathering activities in disaster areas.

B. A Multi-Robot System using an LCX Network as Wireless Communication Infrastructure

An LCX network has a large number of holes called slits in the outer conductor of the coaxial cable that are designed to leak the electrical signal transmitted in the cable to the outside (Fig. 2). Information transmitted by the remote operator to the mobile robot is leaked to the outside as radio waves from the slit of the LCX. Slits can also receive radio waves, enabling mutual communication between the mobile robot and the operator.

Therefore, the LCX can be used as a single antenna by connecting it to a TCP/IP-compliant access point (Fig. 3). By laying LCX, a network can be constructed in a wide area along the cable; thus, LCX can be used as wireless communication infrastructure in a multi-robot environment.

C. Tele-Operation of Multiple Robots using an LCX Network

An information-gathering system for multiple robots on an LCX network in a closed space affected by a disaster is illustrated in Fig. 4 [24]. In the flow of information-gathering activities, a cable-laying robot first lays LCX as the communication infrastructure. Multiple robots that gather information are operated by wireless tele-operation without degrading the running performance by using radio waves leaked from the laid LCX.

The communication protocol of this system uses TCP / IP in consideration of mobile robot installation and tele-operation. At present, it is common to use a general-purpose PC for the control system of the mobile robot, and TCP/IP is often used as a communication protocol for tele-operation. Therefore, in the proposed system, we adopted IEEE802.11g as the communication method of the mobile robot, and we performed tele-operation by packet communication.

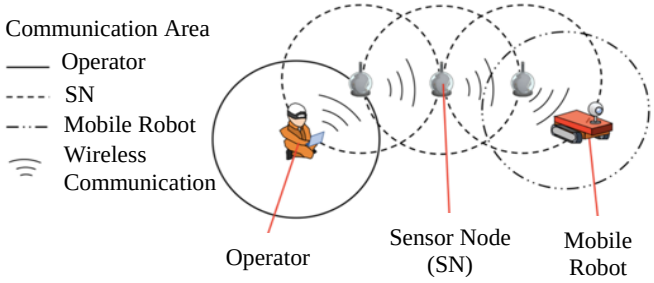

Fig. 1. Robot Wireless Sensor Network (RWSN).

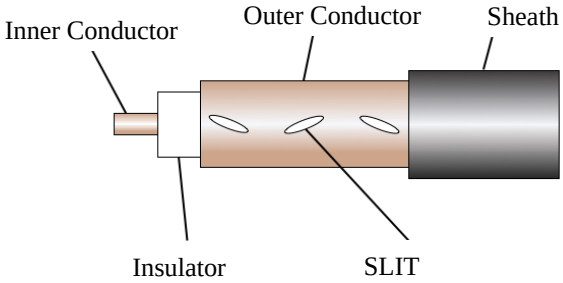

Fig. 2. Internal Structure of the Cable used in an LCX Network.

Fig. 3. An LCX Network Equipped with TCP/IP-Compliant Access Points.

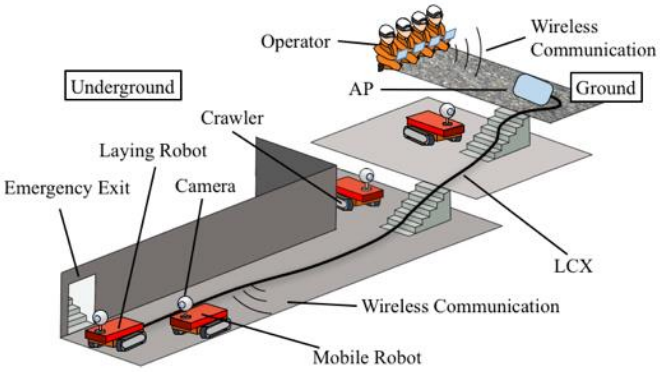

Fig. 4. A Disaster Area Information-Gathering System utilizing LCX Network Construction.

IEEE802.11g has a theoretical throughput value of 54.0 Mbps, which is the amount of data that can be transmitted and received per unit time. Nitta et al. are conducting research on a wireless tele-operation method for excavators by streaming camera images from the excavator to the operator, and reports that wireless tele-operation requires a throughput value of 4.0 Mbps or more. Thus, in the proposed system, the throughput value required for tele-operation between the operator and the mobile robot is set to 4.0 Mbps. IEEE802.11g satisfies the throughput value required for the transmission and reception of streaming and sensor information for tele-operation and command packets used as operation commands, and it can be used in the communication infrastructure of the proposed system.

D. *Considerations for a Multi-Robot System using an LCX Network*

When an operator remotely controls a mobile robot, it is important for the mobile operator to monitor the communication quality between him/her and the mobile robot to prevent decreases in the operability of the mobile robot and disconnection from the network. The communication range of an LCX network becomes narrower from the access point to the end of LCX because the transmitted and received signals are attenuated by the cable length. The throughput value is also reduced because the transmission loss increases with the distance from the access point as the communication range decreases. Additionally, regarding data transmission and reception, if the communication capacity of the communication path exceeds the upper limit, some mobile robots connected to LCX may be disconnected from the network. This is a specification based on TCP/IP to prevent communication failure on the network when the network is heavily loaded and to keep the connected computers as connected as possible. Therefore, it is also necessary for the operator to monitor traffic on communication paths in LCX networks. As mentioned above, traffic monitoring is required to sequentially determine the position information and transmission capacity of each robot because communication characteristics change with distance. An important part of traffic monitoring is determination of the maximum transmission capacity with respect to the distance from the access point of LCX in consideration of the throughput characteristic of the LCX network.

The maximum amount of transmission is the sum of the amount of information transmitted and received through the LCX network. When multiple robots are connected to the LCX network, the maximum transmission amount is divided among all the mobile robots (Fig. 5). However, when transmission and reception exceeding this maximum transmission amount are performed, the network connection cannot be maintained; therefore, a mobile robot is disconnected from the LCX network.

This problem is due to the TCP / IP protocol, and similar disconnects occur in TCP / IP compliant LCX networks like this system. We constructed an LCX network and connected five pairs of operator computers and mobile robots to perform bandwidth compression experiments on communication paths in a virtual multi-robot tele-operation environment.

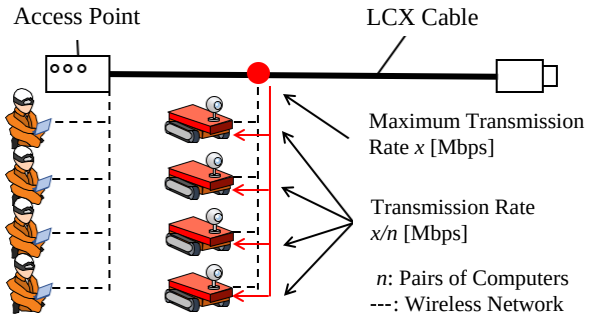

Fig. 5. Fluctuation of Available throughput Value by Band Division in the LCX Network.

In the experiment, the bandwidth division situation was observed with a coiled LCX cable without considering the distance characteristics of the maximum transmission volume (Fig. 6).

The band compression type throughput measurement was performed between all the computers used for tele-operation and the computers assuming mobile robots. The maximum transmission capacity of the LCX network used in the verification experiment was measured to be about 42.0 Mbps. As a result of the band compression experiment, the division of the band was confirmed as illustrated in Fig. 7.

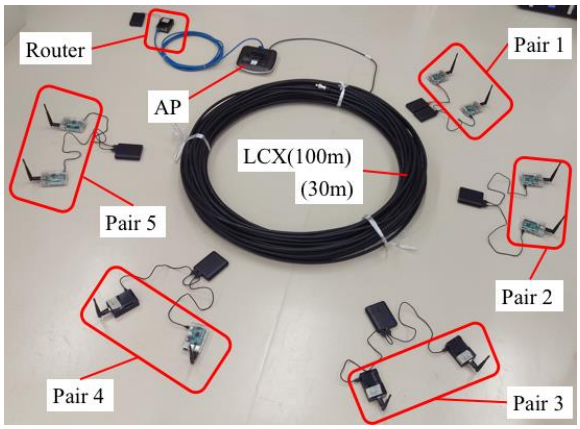

Fig. 6. Observation of a Bandwidth Division Situation in a Coiled LCX Cable without Considering the Distance.

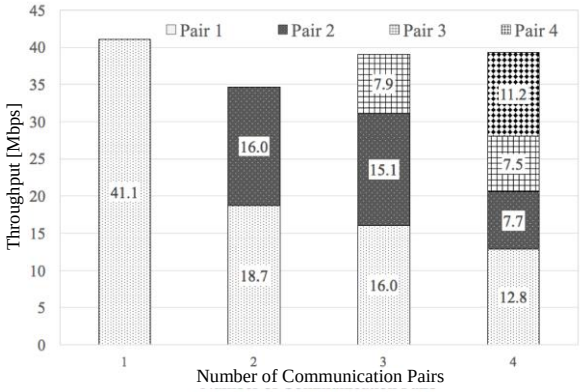

Fig. 7. Throughput Values at Band Division.

When we used one communication pair, the maximum transmission rate was almost the same as 41.1 Mbps. For two or more pairs, band division occurred: for two pairs, the throughput values were 16.0 and 18.7 Mbps; for three pairs, the throughput values were 7.9, 15.1, and 16.0 Mbps; and for four pairs, the throughput values were 7.5, 7.7, 11.2, and 12.8 Mbps. However, for five pairs, the connections of all the computers were canceled because the amount of transmission and reception exceeded the maximum capacity. Therefore, for one to execute tele-operation of a multi-robot system using an LCX network, band division must not be generated because it is likely to cause network disconnection. All tele-operators connected to the network must keep track of the amount of transmission and reception between other pairs and be careful not to exceed the maximum amount of transmission. However, in multi-robot operation using an LCX network, no method has been proposed to constantly determine the amount of transmission and reception between other pairs. In a general computer network, bandwidth division control is performed by the *resource reservation protocol*. However, in the operation of a mobile robot, it is difficult to use the resource reservation protocol because the communication quality changes frequently due to the movement of the robot. Therefore, in this study, we developed a band division prevention method assuming multi-robot operation using an LCX network.

III. A Traffic Monitoring System using Broadcast Packets that Store Transmission Volume Information

This section describes the traffic monitoring system between each tele-operator and a mobile robot, which considers the problems in tele-operation of multiple robots through the LCX network mentioned above. Many methods have been proposed to monitor the communication status on the communication path, but no method has been proposed that considers the operation of the mobile robot. When considering the operation of mobile robots in a disaster area, the type of robot used depends on the type and situation of the disaster. The robots used in the disaster area are not unified, in terms of the structure of the drive system and the type of OS and control system. It is also difficult to estimate the number of mobile robots to be operated. Although many existing communication status monitoring systems are packaged as software, no one software can be introduced to all OSs and communication methods. Additionally, no method has been proposed that uses multiple mobile robots. Thus, in this study, we propose a communication condition monitoring method using broadcast packets on the premise of TCP/IP-based network connection. A broadcast packet-based method can be used freely in TCP/IP-compliant communication, and it can be used regardless of the operating system or communication method. It can also be used regardless of the number of mobile robots connected to the network. Therefore, it is a method that can be implemented in many mobile robot systems.

Fig. 8 presents the flowchart of the proposed system. The tele-operation method prevents band division by determining the maximum transmission value of the communication path and the traffic between other tele-operators and mobile robots and then adjusting the amount of transmission and reception. Additionally, broadcast packets are used for traffic monitoring. Broadcast packets are packets that can be sent to all computers connected to the same network. The mobile robot calculates traffic information from the measurement of transmission and reception information with the tele-operator and then stores the traffic information in a broadcast packet (Fig. 9). For the measurement, we decided to calculate the traffic per unit time. Packets storing traffic information are sent to each computer on the network once per second. Each tele-operator refers to the received broadcast packet and monitors the traffic between other tele-operators and mobile robots sequentially. Then, the tele-operator can prevent communication disconnection due to band division between each mobile robot and the network by controlling the transmission amount before band division occurs. In existing traffic monitoring methods, generally, many methods use bandwidth for traffic measurement packets. In this study, considering the characteristics of the LCX network, we developed a non-bandwidth compression type traffic monitoring system using only broadcast packets.

In the next section, we construct an LCX network that implements the proposed method, and we describe the broadcast transmission and reception experiments.

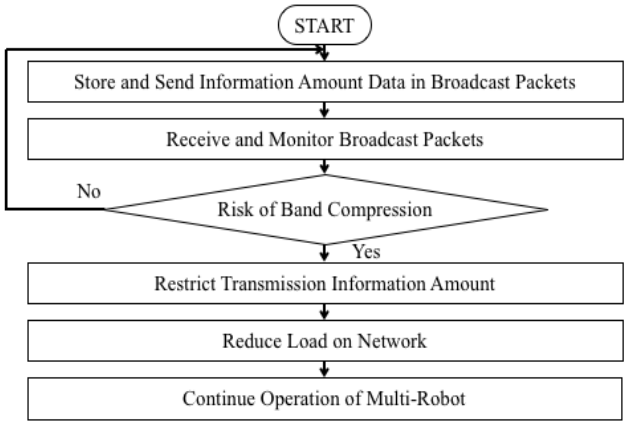

Fig. 8. Flowchart of the Communication Prevention System.

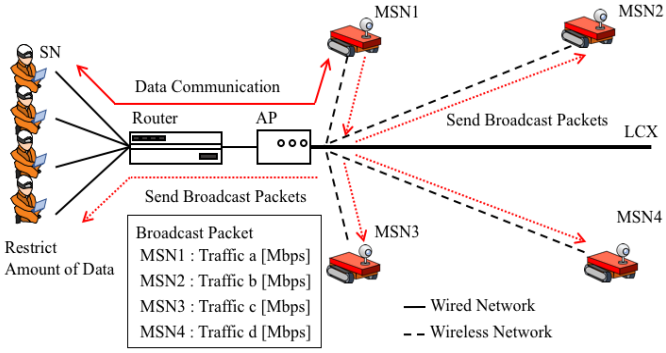

Fig. 9. Proposed Method using Broadcast Packets in a Multi-Robot System.

IV. Evaluation Experiment of the Traffic Monitoring System using Broadcast Packets

A. Evaluation of Packet Loss of the Traffic Monitoring System in an LCX Network using Broadcast Packets

The purpose of this experiment is to confirm that broadcast packets can be received in an environment where communication load is applied to the communication band. The communication load that can be applied to the communication band is set by assuming the load when information is transmitted and received. In this experiment, we constructed an IEEE 802.11g network using LCX in a real environment and evaluated the availability of the proposed method by transmitting and receiving broadcast packets. The equipment used for the experiment adopted Raspberry Pi2 (Model B) for the control system of the tele-operator and the mobile robot, and LCXF-8D-LCX (HC Networks, Ltd.) for LCX. In addition, AP-214 (Aruba Networks, Ltd.) was used as the access point compliant with TCP/IP. Broadcast packets were sent and received by connecting four tele-operator computers and four computers simulating mobile robots to the LCX network. To put a sufficient communication load on the LCX network, we used four pairs of tele-operators and mobile robots.

B. The Experimental Environment

Fig. 10 presents the network construction diagram of the network constructed in the experiment. The experimental environment is illustrated in Fig. 11. This experiment was conducted by laying 100 m of LCX in a straight path where no other wireless LAN existed. The tele-operation computer and the mobile robot were placed at a distance of 0.3 m in the vertical direction from the LCX. For communication between the mobile robot and the remote operator, UDP protocol was adopted in consideration of the requirement for real-time tele-operation. Tele-operator computers and computers simulating mobile robots were all assigned static IP addresses in consideration of the requirement for using this system in a multi-robot environment. The network configuration in Fig. 3 looks like a bus-type topology, but this network topology was set as star-type in consideration of the ease of connection setup (Fig. 12).

C. Broadcast Packet Transmission and Reception Experiment

In this experiment, computers (MSNs 1 to 4) assuming four mobile robots were placed on one mobile robot, and measurement was performed while moving the mobile robots. Tele-operation computers (SN1–4) and the mobile robots (MSN1–4) were placed at 0 m in measurement environment, and an arbitrary communication load was applied on the communication path between SN1-MSN1 and SN3-MSN3. Next, computers other than SN2 were set to the broadcast packet reception standby mode. In an environment where the communication load is applied to the network, SN2 transmits a broadcast packet that contains information that assumes the amount of data actually transmitted and received 10 times. After that, we checked whether the computers in the reception mode could receive the information stored in the packet. For packet reception confirmation, the number of packet losses was counted as an evaluation of packets that could not be received. The communication loads on the communication path were 5.0, 10.0, 15.0, 20.0, 25.0, and 30.0 Mbps. When the communication load applied to the network was 5.0 to 15.0 Mbps, SN1 generated the communication load. The communication load up to 20.0–30.0 Mbps was generated by SN1 and SN3. In addition, MSN1–4 was moved from 0 m to 100 m at intervals of 10 m, and evaluation experiments were conducted at each 10 m interval.

D. Experimental Results

The experimental results are illustrated in Fig. 13 to 19. The vertical axis represents the number of packet losses, and the horizontal axis represents the distance traveled by each MSN from the access point to the end of LCX. The measurement results for each communication load are presented for each SN and each MSN. From the results of this experiment, we confirmed that the communication load applied to the LCX network is large, and the number of packet losses increases. Additionally, in this experiment, network troubles such as disconnection of communication did not occur at all measurement points, and the mobile robot could be operated in all areas.

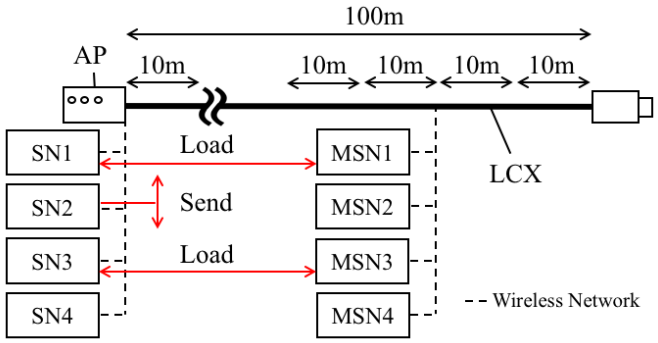

Fig. 10. Network Construction Diagram of Network Constructed in this Experiment.

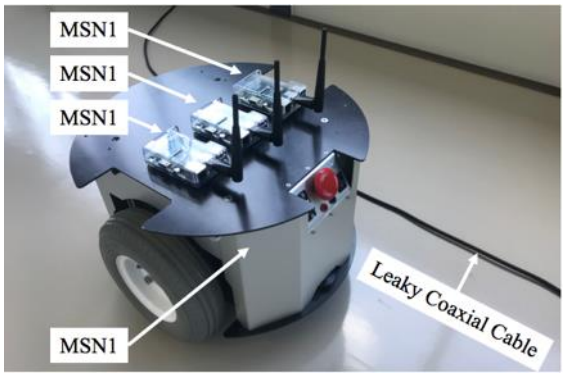

Fig. 11. Experimental Environment of the Proposed Method using Broadcast Packets.

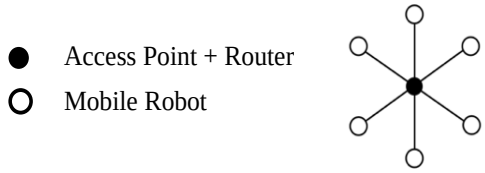

Fig. 12. Wireless Network and Mobile Robot Network Topology Constructed using LCX.

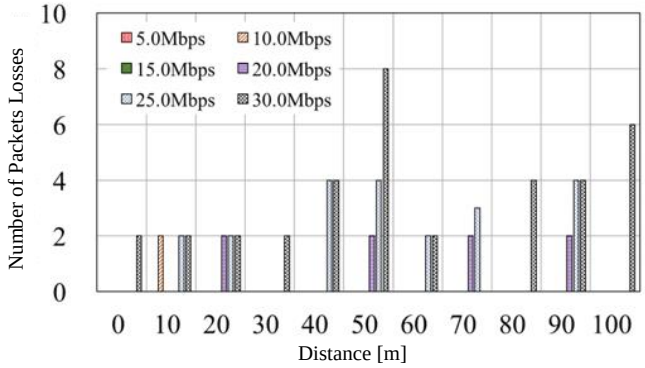

Fig. 13. Number of Broadcast Packet Losses (SN1).

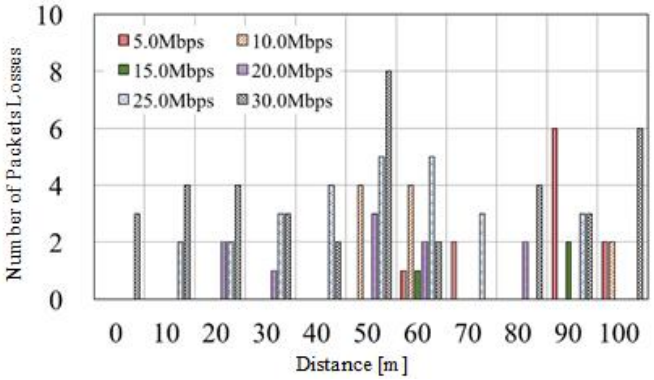

Fig. 14. Number of Broadcast Packet Losses (MSN1).

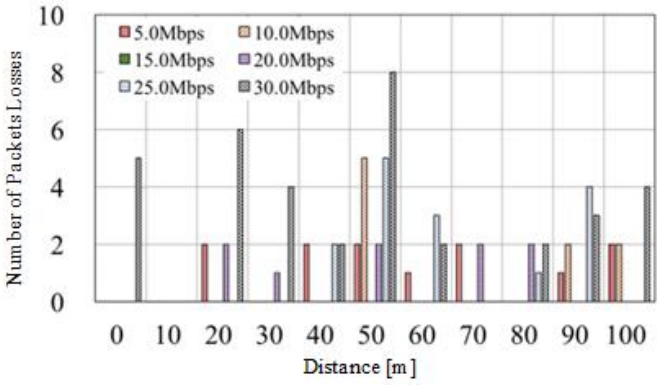

Fig. 15. Number of Broadcast Packet Losses (MSN2).

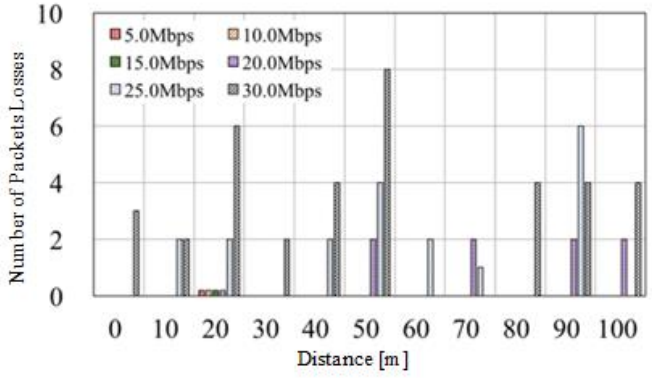

Fig. 16. Number of Broadcast Packet Losses (SN3).

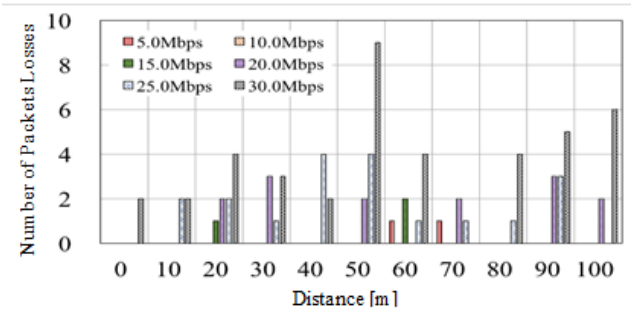

Fig. 17. Number of Broadcast Packet Losses (MSN3).

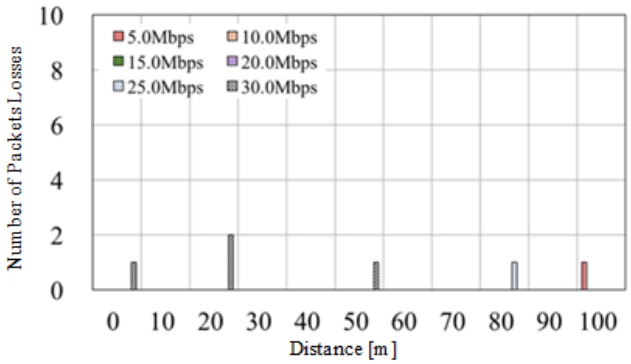

Fig. 18. Number of Broadcast Packet Losses (SN4).

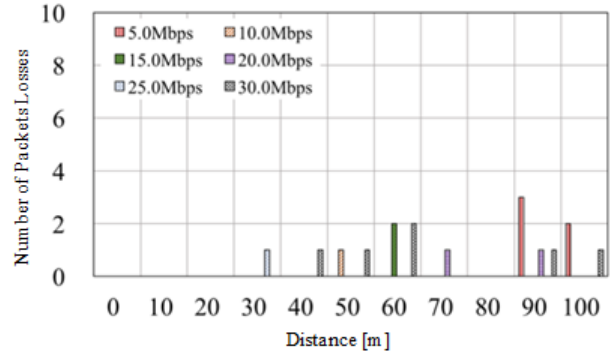

Fig. 19. Number of Broadcast Packet Losses (MSN4).

V. Discussion

From the experimental results, it was confirmed that it was possible to determine the communication situation used between each remote operator and a mobile robot connected to the LCX network using the proposed method. The number of packet losses is smaller in each SN than in each MSN. This is thought to be due to the fact that SN2 and other SNs that transmit broadcast packets are placed at the 0 m point, so the effects of transmission loss of electrical signals in the LCX cable and environmental noise are small. In addition, packet loss was unlikely to occur in each MSN in the range of 0–40 m while the communication load applied to the communication path was 5.0–15.0 Mbps. This is considered to be due to the fact that the start point of the LCX network was smaller in transmission loss and higher in throughput than the end of the LCX network. Therefore, in the end area of LCX (80–100 m), packet loss occurred even when a communication load of 10.0–15.0 Mbps was applied. Further, as the reason why the number

of packet losses is not constant, it is conceivable that the communication load changes somewhat due to the change of the communication environment. Furthermore, in this experiment, it was confirmed that broadcast packets were delivered to other computers, although packet loss occurred when the communication load was within 30.0 Mbps. Hence, it is considered that the proposed method can prevent the decrease of the transmission amount and communication division due to band division by determining the maximum transmission amount of the communication route to be used. In this experiment, IEEE 802.11g was adopted as the communication method, but even when other communication methods are adopted, this method can be used to determine the maximum transmission amount of the communication path.

VI. Conclusion

In this paper, as a method to prevent disconnection in remote operator–mobile robot communication due to bandwidth compression assuming a multi-robot environment constructed using LCX, a bandwidth non-compression type communication status determining system using broadcast packets was proposed. In LCX cables, the transmission loss of electrical signals increases from the beginning to the end of the cable. The loss of the electrical signal affects the radio waves leaking from the LCX, and the throughput value also decreases. Moreover, when multiple robots connected to LCX are at the same distance from the access point along LCX, the maximum amount of transmission that can be communicated between each remote operator and a mobile robot is divided into bands. The decrease of the throughput value and the bandwidth division reduce the amount of transmission available per mobile robot. As a result, the amount of transmission necessary for tele-operation cannot be secured, and the risk of communication disconnection is increased. In this paper, we proposed a system of preventing communication disconnection and band division by using broadcast packets to obtain information on the transmission amount that each mobile robot connected to LCX transmits and receives for tele-operation. Remote operators can pay attention to communication disconnection and band division because other remote operators can share the amount of transmission that other mobile robots are transmitting and receiving.

For the evaluation experiment of the proposed method, an LCX network was constructed, and its effectiveness was confirmed using a remote operator computer and a mobile robot. The number of broadcast packet losses increased when the communication path was overloaded or when the distance from the access point was increased. If broadcast packets cannot be received, it is not possible to determine the amount of transmission and reception of other mobile robots, so the risk of communication disconnection increases. However, in this experiment, broadcast packets were transmitted 10 times, but in all evaluations, no situation occurred in which packets could not be received. We also consider that the reduction of the number of packet losses can be dealt with by increasing the number of broadcast packet transmissions.

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Developing an Integrated Cloud-based Framework for Securing Dataflow of Wireless Sensors

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***Abstract*—Cloud computing environment has been developed rapidly and becomes a popular trend in recent years. It provides on-demand services to several applications with access to an unlimited number of resources such as servers, storage, networks. Wireless Sensor Network, on the other hand, has been enormously progressing in various applications and producing a considerable amount of sensor data. Sensor networks are based on a group of interconnected small size sensor nodes that can be distributed over different geographical areas to observe environmental and physical phenomena. Nevertheless, it has limitations concerning power, storage, and scalability that need to be addressed adequately. Integrating wireless sensor networks with cloud computing can overcome these problems. Cloud computing provides a more secure and high available platform for effective management of sensor data. This paper proposes a framework to secure the dataflow of sensor devices from wireless sensor networks to cloud computing using an integrated environment. The framework presents an authentication scheme to validate the identity of sensor devices connected to the cloud environment. Furthermore, it provides secure environments with high availability and data integrity.**

Keywords*—Framework; security; wireless sensor; cloud computing; data integrity; availability

I. Introduction

Cloud computing is a flourishing technology that has appeared in the commercial sector of information technology [1]. Its paradigm can make computer software more attractive as a service. It eliminates the need for setting up a large number of physical devices or operating the infrastructure while requiring experts and technical support [2]. Cloud Computing is Internet-based computing where resources allocations are shared. It provides software and information to the computer and all other devices on demand as requested. IBM declared that cloud computing is a novel model for using and delivering several IT-based services [3]. It allows transparent access to cloud services without the need for recognizing the underlying technologies or implementation.

Some common issues, such as security, pricing models, scheduling, and integration of different applications, are resolved using cloud computing [4]. Moreover, the accessibility of essential resources such as memory, bandwidth, storage, servers, and networks are supported by cloud computing. Furthermore, the "pay as you use" services are considered. Fig. 1 shows the general architecture of cloud computing.

Security and privacy are the most critical challenges in cloud computing [5]. Security relies on a group of techniques that protect sensitive data from the vulnerable attacks and ensure data integrity, authentication, and confidentiality [6]. Privacy ensures that users can control their sensitive data.

The security issues cover several areas, including operating systems, networks, virtualization, databases, resource scheduling, load balancing, and memory management [7]. For example, the network that links systems or applications must be secure.

On the other hand, Wireless Sensor Networks (WSNs) are self-organizing networks that implemented vastly in various applications. WSNs consist of a group of spatial distributed multifunctional sensors [8]. These sensors have the capabilities of transmitting or monitoring significant environmental or physical situations such as temperature, humidity, pressure, and sound. Interconnected sensors sense the surrounding environment and transfer sensed data to master or sink nodes [9]. Fig. 2 shows the general structure of WSNs.

WSNs become a significant trend in different domains in industrial, commercial, governmental, entertainment, medical, military, transportation, city management, smart spaces, and environmental applications [10]. However, there are still several security issues due to limitations in regards to communication and interconnectivity. These issues include confidentiality, integrity, authentication, availability, and freshness of sensor data [11]. Besides, WSNs face many challenges as the resources of sensor nodes suffer from low power, cost, storage capacity, and bandwidth availability.

WSNs are exposed to various threats and attacks where the attacker can access the sensor node. WSNs security is associated with some main requirements, including integrity, authentication, freshness, confidentiality, and availability [12]. Therefore, an integrated platform is needed to secure data sent from WSNs and to ensure security requirements for cloud computing.

This paper presents a secure framework that provides a secure dataflow from sensor nodes to cloud computing in an integrated environment. An effective authentication scheme is developed to validate the identity of sensor devices using their sensor serial number and geographic location. Moreover, efficient encryption techniques are used to secure data sent from sensors to cloud computing, such as public key encryption (RSA) and symmetric key encryption (AES). In addition, data integrity is addressed in the framework using the hashing technique. Furthermore, Scyther analyzer protocol tool is used to analyze and validate the proposed security solutions.

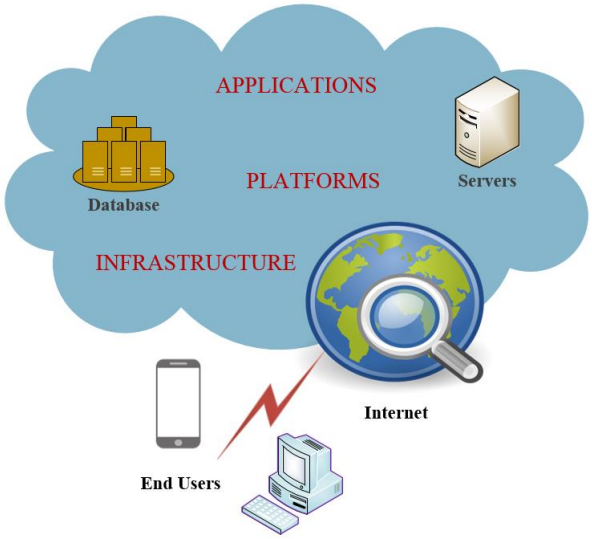

Fig. 1. General Architecture of Cloud Computing.

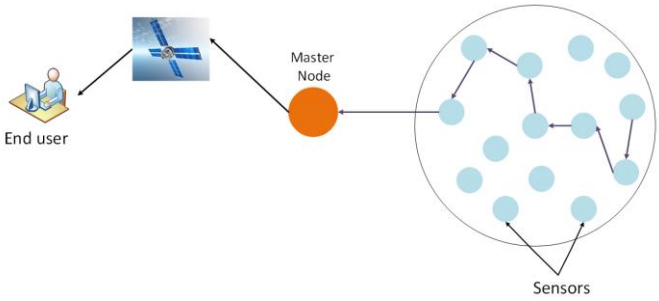

Fig. 2. General Structure of WSNs.

The rest of the paper is organized as follows: In Section II, a literature review is presented. Section III introduces the architecture of the proposed integrated framework. The design and analysis of a secure framework are presented in Section IV. An implementation of the proposed framework is presented in Section V. Finally, Section VI discusses and analyzes the implementation results of the proposed framework.

II. Literature Review

This section presents an overview of some related approaches that have been proposed for integrating WSNs with cloud computing.

In [3], the authors proposed a new framework for wireless sensor networks integration with a Cloud computing model. This framework shows how the data is shifted from WSN to cloud computing. Reliability and availability of wireless sensor networks will be promoted by applying cloud computing. The proposed system has its useful applications and significant role in the medical sciences field.

A method for processing the sensory data in wireless sensor networks and mobile cloud computing (WSN–MCC) integration is introduced in [13]. It addresses the critical issues concerning WSN–MCC integration. Also, the authors proposed a framework for a novel sensory data processing, for transmitting available sensory data to the users in a fast, reliable, and secure manner. Analytical and experimental results are presented to explain that the proposed framework can improve the network lifetime, the storage requirement, the security and monitoring performance of WSNs, and the security of the transmitted sensory data.

Authors in [14] proposed a flexible, secure scheme for data-centric applications in cloud computing based scenario. They have taken healthcare application as a case study to show the performance analysis of the proposed security method. They have tried to eliminate potential security threats and guarantee fast and flexible security solutions to the fundamental security requirements.

In [15], the authors proposed a Sensor-cloud infrastructure to provide a flexible platform which shares a vast amount of sensor data from various applications. They focus on the processing of sensor data with the collaboration of WSN and cloud securely to access the sensor cloud resources using authentication and access control. The authors propose a new data processing framework to integrate wireless sensor networks with cloud computing. Furthermore, in sensor-cloud infrastructure, the identity-based cryptography is proposed to facilitate key distribution and authentication.

A unique based framework is introduced in [16] for integrating body area network with cloud computing. This framework uses the concept of publish/subscribe (pub/sub) broker. The methodology of this framework is implemented by transmitting the gathered sensitive data from the patient to the web application on cloud computing. The simulation result indicated that internal attack detection works well.

The authors in [17] proposed an integrated architecture of wireless sensor networks and cloud computing in an agricultural environment. This paper aims to simplify the shifting of data from wireless sensor networks to cloud computing. The integrated architecture consists of three levels including Sensing Data Level, Cloud Service Level (SAAS, PAAS, and IAAS) and Control Level. Furthermore, the development of the agricultural environment management (AEMS) system is based on the architecture of WSNs and cloud computing. The testing results of temperature and humidity data that are collected from wireless sensors and AEMS are presented.

Since the embedded systems are limited in resources, storage, and computing, a framework in [18] is presented to extend the local resources of these embedded systems. Scalability and high availability are provided in this framework. In order to manage the use of cloud computing to minimize computation cost and execution time, they implement a scheduling algorithm. If the task requires high computation, it is applied in cloud computing, while in case of medium and low computations, they are implemented in the local servers and embedded systems. Moreover, windows azure services are used to implement this framework. They used response time and throughput metrics in order to evaluate the performance of the implemented framework.

In order to provide confidentiality, authenticity, integrity, and privacy of wireless sensor networks, the authors in [19] have proposed a framework to secure data delivery in WSNs.

They use private cloud computing to increase computation resources and storage. Also, to simplify data retrieval, Elliptic curve cryptography is used in this framework for encryption and decryption of collected data. To prevent some attacks and secure the framework, the authors suggest some detection and security measurement. Moreover, this framework is implemented in the medical field. Finally, they validate the performance and robustness of the framework by using performance and security analysis.

III. Proposed Framework Architecture

The proposed framework securely integrates wireless sensor networks environment with cloud computing. Fig. 3 shows the general architecture of the proposed framework to secure dataflow from WSNs environment to cloud computing platforms. The framework consists of the following several components: sensor nodes, sensor gateway, integration unit, Management unit, access policy unit, and cloud platforms (databases, servers, and processing unit).

The sensor nodes are distributed in different fixed geographical locations, and each sensor is identified by a unique identifier. A combination ID consists of serial number and current geographical location where the sensor node is located is used to identify each sensor node. Latitude and longitude values of sensor's location are concatenated to the sensor id as salt, and then the salted id is hashed to make the dictionary attack more difficult.

The sensed data is passed from sensor nodes to the sensor gateway directly. The gateway collects sensed data from sensors, computes the hash code of collected data, and then encrypts both data and hash using a symmetric-key encryption method.

The integration unit is used as a temporary buffer and to forward the encrypted data from the sensor network environment to cloud computing. After the data is passed to cloud computing, the cloud controller will rely on the policy management unit to authenticate the identity of each sensor node. If the sensor device is identified, the sensed data will be forwarded to the application server in cloud computing for decrypting received data and applying data integrity technique.

The load balancer distributes the workload stream across multiple application and database servers to improve overall availability and achieve high performance.

On the right side of Fig. 3, the rectangle components show the security requirements in each phase during transmitting data from sensor devices to cloud computing. The sensor data is protected by authentication, confidentiality, and integrity techniques at the sensor gateway. During the transmission of sensor data from a wireless sensor network to cloud computing, a secure connection is provided.

The authentication of sensor nodes is performed by the application server on the cloud side to check their identity. Furthermore, availability, confidentiality, and integrity of data will be provided in cloud computing.

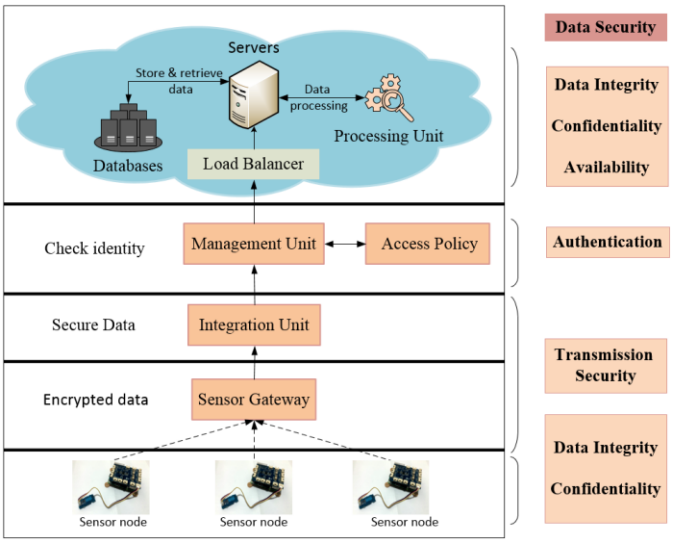

Fig. 3. An Integrated Framework Architecture.

In the suggested framework, security requirements are provided as follows:

- Authentication is provided for each sensor device using its serial number and current geographical location.
- Confidentiality is the encryption and decryption of data transmitted from sensors to cloud computing.
- Data Integrity is provided by using a hashing technique to ensure that the transmitted data have not been modified during transmission.
- Availability is guaranteed by cloud computing, which provides access to an unlimited number of resources.

IV. Framework Design and Analysis

A. Operations Design

This section demonstrates the primary operations of the proposed framework. The serial number and geographical location of the sensor device are used to validate the identity of each device using the authentication scheme explained in the next section.

Data encryption is implemented using symmetric key cryptography. In addition, a hashing technique was implemented for data integrity.

Fig. 4 shows a flowchart for the process of sending data at the sensor side. It illustrates how the sensed data moved toward cloud computing.

In the beginning, each master node (gateway) reads its serial number and current geographical location and then attempts to connect to the cloud controller. The sensor device is logged in to cloud computing if it is already registered. Otherwise, it carries out the registration process first. After that the master node collects sensed data from other sensor nodes, and then hashes the sensed data. Symmetric-key encryption algorithm encrypts both hashed and sensed data before transmitting them to cloud computing.

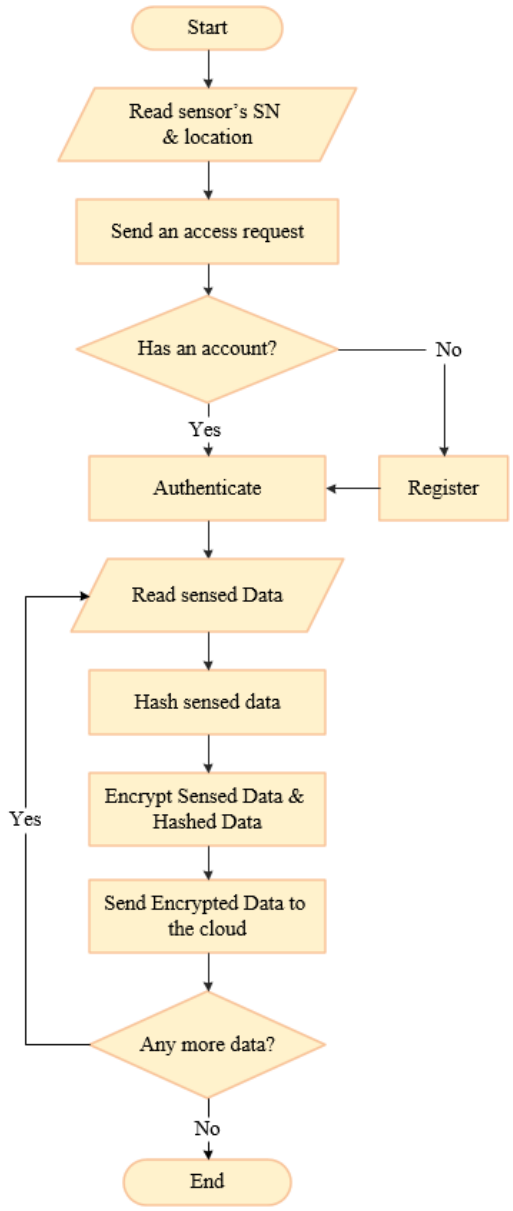

Fig. 4. Flowchart for Sending Data at the Sensor Side.

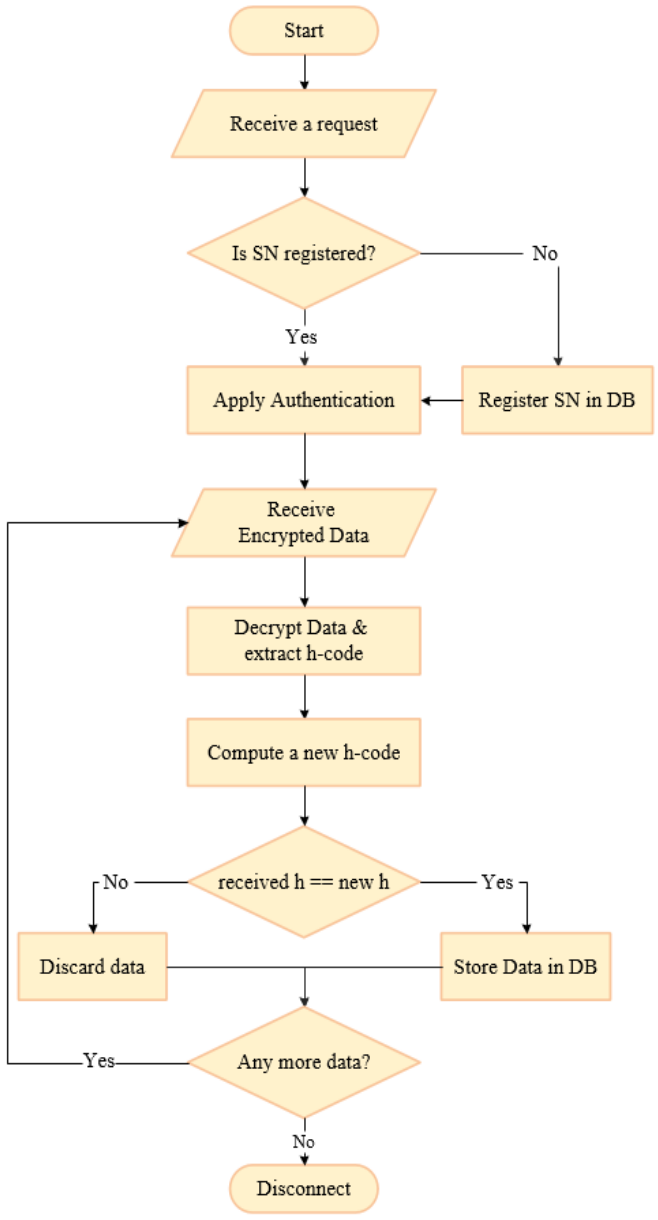

Fig. 5. Flowchart for Receiving Data on the Cloud-Side.

Fig. 5 shows a flowchart for the process of receiving data on the cloud-computing side. Upon the reception of the encrypted data at cloud computing, the data is decrypted using the same symmetric encryption. The cloud controller computes a new hash value of the sensed data and compares it with that sent with sensed data. If they match, it stores data to the database, otherwise, discards it.

B. Authentication Scheme Design

The authentication scheme suggested in [20] has been developed in the framework to authenticate the identity of master sensor nodes (SN) before transmitting data towards the cloud controller (CC).

This proposed scheme includes registration and authentication phases. Fig. 6, and 7 show the sequence diagrams of both registration and authentication phases.

In the beginning, the master node generates a varying time nonce *ni* and sends a connection request to the cloud controller after encrypting it using public-key cryptography method. The encrypted request involves the sensor's serial number *sn* and generated nonce *ni*. Upon receiving a request, the cloud controller checks its log-file, if the sensor node is not registered, the registration phase starts when the cloud controller creates an account for the sensor device as shown in Fig. 6.

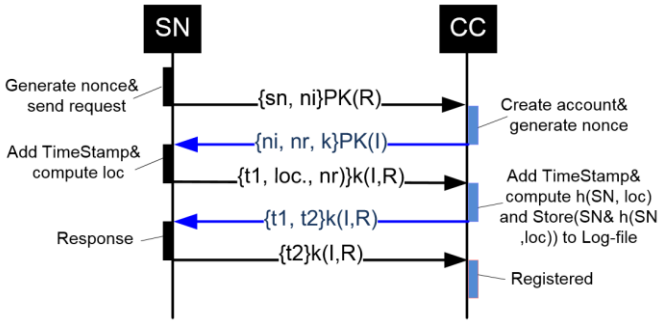

Fig. 6. The Registration Phase.

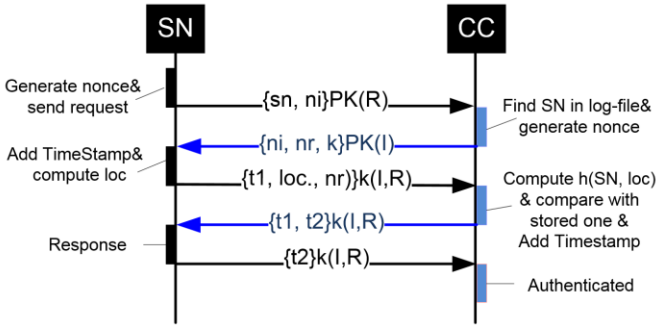

Fig. 7. The Authentication Phase.

While if the sensor node is already registered, the authentication phase starts as shown in Fig. 7.

In the next steps of both phases, the cloud controller generates its nonce *nr*, and then encrypts it with a new session key *k* and sensor's *ni* using the public key of SN before sending the response back to the node. The session key will be used for encrypting any data sent from the SN toward CC. When the SN receives the message sent from the CC, it will decrypt it using its private key and will compare its generated nonce with the nonce comes back from CC. If they are not matched, it will interrupt the connection. The timestamp *t1*, *nr*, and sensor's geographical location *loc* are sent to the CC after encrypting them by symmetric encryption method using the session key *k*. On the cloud side, nonces are compared as same as in the sensor side. If they are not matched, the controller will close the connection.

After that, the CC computes the hash value of concatenated *sn* and *loc* of the SN, store hashed value to the sensor's account and then sends encrypted *t2* with *t1* to the SN. After receiving a response from SN, the CC accomplishes the registration. In case the SN already has an account, the CC compares the computed hashed value with that value stored in log-file to grant or deny the connection. Otherwise, the sensor device is authenticated and ready to send data securely.

C. Authentication Scheme Evaluation Results

In this section, Scyther analyzer tool [21] is used to ensure and validate the security of the authentication phase. In this analysis, the authentication scheme is examined against a set of potential attacks. Each row shows the analysis at each process and whether there are attacks or not. Fig. 8 shows the analysis results of the authentication scheme.

Claim				Status		Comments
Authentication	I	Authentication,i2	Secret ni	Ok	Verified	No attacks.
		Authentication,i3	Secret nr	Ok	Verified	No attacks.
		Authentication,i4	Secret k	Ok	Verified	No attacks.
		Authentication,i5	Secret t1	Ok	Verified	No attacks.
		Authentication,i6	Secret t2	Ok	Verified	No attacks.
		Authentication,i7	Secret loc	Ok	Verified	No attacks.
		Authentication,i8	Secret SN	Ok	Verified	No attacks.
		Authentication,i9	Alive	Ok	Verified	No attacks.
		Authentication,i10	Weakagree	Ok	Verified	No attacks.
		Authentication,i11	Niagree	Ok	Verified	No attacks.
		Authentication,i12	Nisynch	Ok	Verified	No attacks.
		Authentication,i13	Commit R,ni,nr	Ok	Verified	No attacks.
	R	Authentication,r2	Secret ni	Ok	Verified	No attacks.
		Authentication,r3	Secret nr	Ok	Verified	No attacks.
		Authentication,r4	Secret k	Ok	Verified	No attacks.
		Authentication,r5	Secret t1	Ok		No attacks within bounds.
		Authentication,r6	Secret t2	Ok		No attacks within bounds.
		Authentication,r7	Secret loc	Ok	Verified	No attacks.
		Authentication,r8	Secret SN	Ok	Verified	No attacks.
		Authentication,r9	Secret h(SN,loc)	Ok	Verified	No attacks.
		Authentication,r10	Alive	Ok	Verified	No attacks.
		Authentication,r11	Weakagree	Ok	Verified	No attacks.
		Authentication,r12	Niagree	Ok	Verified	No attacks.
		Authentication,r13	Nisynch	Ok	Verified	No attacks.
		Authentication,r14	Commit I,nr,ni	Ok	Verified	No attacks.

Fig. 8. Authentication Scheme Analysis.

The initiator and receiver roles represent both sensor and cloud controller sides. The sensor node is represented by 'I' while the cloud controller is represented by 'R'.

During the authentication phase, all sensitive sensor data will be selected as claims. The claim statements ensure secret data. Different types of claims are defined as follows:

Secret: It means the term must be secret.

Alive: It checks the aliveness of all roles. In other words, it checks that the roles are communicating with each other.

Weakagree: To guarantee complete running all the claims in the role during the weak agreement.

Niagree: To guarantee complete running all the claims in the role during the non-injective agreement.

Nisynch: Means that the synchronization is non-injective.

Commit: It represents effective claims.

Under the status, there are two columns show whether the claim is correct and verified or not. The last column shows the comment, which explains the status of the result and whether there are some attacks or not.

Scyther analyzer results, as shown in Fig. 8 prove that all sensitive information exchanged between the sensor node and cloud controller during the authentication phase is secure and protected against any potential attack.

V. Framework Implementation

This section describes the implementation of the suggested integrated framework between cloud computing and WSNs. The wireless network consists of two master nodes (raspberry pi) distributed in different distant geographical locations connected with three sensors. The first master node connected with temperature and humidity sensors, and the second one placed in another location and connected with an air quality sensor. Sensors sense the surrounding environment and transmit sensed data every 5 seconds to the cloud computing for storing in the database. All sensors run simultaneously in different and discrete times. They were connected to the cloud environment for three days continuously, and sometimes for a few hours or even for a few minutes.

The private cloud of Qassim University has been used to implement the framework using Apache Cloud Stack platform. Two application servers and one database server have created in the cloud. Sensor nodes connect to the cloud computing through a load balancer, which works as a gateway to forward the workloads to the most appropriate application server. The application server decrypts the sent data and ensures data integrity before transmitting it to the MySQL database server. The client and cloud servers' codes have been written using Python programming language.

VI. Implementation Results and Analysis

A. Data Integrity Testing

The accuracy of data has been tested every time it is transmitted or processed and stored in the DB server.

The integrity test is applied to 77167 records of data stored in the database. When the cloud server receives sensed data and its hash value, it computes a new hash value and then compares it with that value sent from the sensor node to provide integrity. Checking these two hashed value proves if data being modified or missed after transmitting or during processing.

Received data and hashed values are stored in DB. If values are same, the data status in DB assigned to '0', i.e., data is not modified as shown in Fig. 9; otherwise, data status will be '1'.

As a result, 77029 records with status '0' and 138 records only with status '1'. As noted during the experiment, the status becomes '1' only at the beginning of connection for the first packet sent from the temperature and humidity sensors, and then, the "0" state continues until the end of the connection, which leads to stability during sensor data transmission. On the other hand, sometimes the status becomes '1' when intentionally connection is interrupted during transmission.

SensorValues	dataType	HsensorValue	newHASH	RecordTime	status	RSerialNo
22.0	T	cb30211d8e…	cb30211d8e9…	2019-02-28 15:58:28	0	000000009db266b5
54	A	2fca346db6…	2fca346db656…	2019-02-28 15:58:31	0	00000000d22c7fa0
20.0	H	585348dbd2…	585348dbd28…	2019-02-28 15:58:33	0	000000009db266b5
53	A	2858dcd105…	2858dcd1057…	2019-02-28 15:58:36	0	00000000d22c7fa0
22.0	T	cb30211d8e…	cb30211d8e9…	2019-02-28 15:58:38	0	000000009db266b5
53	A	2858dcd105…	2858dcd1057…	2019-02-28 15:58:41	0	00000000d22c7fa0
20.0	H	585348dbd2…	585348dbd28…	2019-02-28 15:58:43	0	000000009db266b5
53	A	2858dcd105…	2858dcd1057…	2019-02-28 15:58:46	0	00000000d22c7fa0
22.0	T	cb30211d8e…	cb30211d8e9…	2019-02-28 15:58:48	0	000000009db266b5
54	A	2fca346db6…	2fca346db656…	2019-02-28 15:58:51	0	00000000d22c7fa0
20.0	H	585348dbd2…	585348dbd28…	2019-02-28 15:58:53	0	000000009db266b5
52	A	41cfc0d1f2d…	41cfc0d1f2d1…	2019-02-28 15:58:56	0	00000000d22c7fa0
22.0	T	cb30211d8e…	cb30211d8e9…	2019-02-28 15:58:58	0	000000009db266b5
53	A	2858dcd105…	2858dcd1057…	2019-02-28 15:59:01	0	00000000d22c7fa0
20.0	H	585348dbd2…	585348dbd28…	2019-02-28 15:59:03	0	000000009db266b5
52	A	41cfc0d1f2d…	41cfc0d1f2d1…	2019-02-28 15:59:07	0	00000000d22c7fa0
22.0	T	cb30211d8e…	cb30211d8e9…	2019-02-28 15:59:08	0	000000009db266b5
54	A	2fca346db6…	2fca346db656…	2019-02-28 15:59:12	0	00000000d22c7fa0
20.0	H	585348dbd2…	585348dbd28…	2019-02-28 15:59:13	0	000000009db266b5
59	A	3e1e967e9b…	3e1e967e9b7…	2019-02-28 15:59:17	0	00000000d22c7fa0
22.0	T	cb30211d8e…	cb30211d8e9…	2019-02-28 15:59:18	0	000000009db266b5
54	A	2fca346db6…	2fca346db656…	2019-02-28 15:59:22	0	00000000d22c7fa0
20.0	H	585348dbd2…	585348dbd28…	2019-02-28 15:59:23	0	000000009db266b5
52	A	41cfc0d1f2d…	41cfc0d1f2d1…	2019-02-28 15:59:27	0	00000000d22c7fa0
22.0	T	cb30211d8e…	cb30211d8e9…	2019-02-28 15:59:28	0	000000009db266b5
55	A	02d20bbd7e…	02d20bbd7e3…	2019-02-28 15:59:32	0	00000000d22c7fa0
20.0	H	585348dbd2…	585348dbd28…	2019-02-28 15:59:33	0	000000009db266b5
53	A	2858dcd105…	2858dcd1057…	2019-02-28 15:59:37	0	00000000d22c7fa0

Fig. 9. Sample of Sensed Data Stored in DB.

According to the counted zeros and ones, the following evaluation metrics are considered:

-True Positive (TP): 77029 records with equal hashes and status '0';

-False Positive (FP): 0 record with not equal hashes and status '0';

-False Negative (FN): 0 record with equal hashes and status '1';

-True Negative (TN): 138 records with not equal hashes and status '1'.

Furthermore, in order to test the correctness of integration procedures, the received data is first injected with random synthesis data, and the computed hashed value is manually modified to ensure that the system can detect any changes on security procedures. These two measurements were repeated several times with the same results.

B. Availability Testing

In order to assess the availability of the proposed system, load testing is applied in the cloud environment. System availability is checked to make sure that the system is running regularly even if a portion of network or hardware fails. In order to achieve this goal, Cloud-based loading tests are accomplished to handle a large number of requests; in addition, to managing an unlimited number of resources in the cloud.

Apache JMeter tool has been used to generate a high load test. Three VMs were created (one VM as a master and the other two machines as slaves) to produce a large number of virtual users. The master-VM is responsible for distributing the load of a large number of requests among the slaves-VMs. While the slaves-VMs perform the commands of the master by sending requests to the target system, and then they send the results back to the master. The target is an application server, where the load test will be executed.

Response time and throughput are measured to assess the performance of the cloud system. Response time is a total time the system takes to respond to a service request, while the throughput is the number of successful requests sent over a communication channel.

Initially, three virtual-users have been started and executed ten times for each slave, i.e., each slave executes 30 requests. The number of users is increasing exponentially. Both local and remote machines have been tested separately.

Fig. 10 shows the system performance of executing a different number of requests by evaluating local and distributed remote machines.

In local testing, the test is conducted using a single machine. The result shows that the system has high performance if the number of requests is less than 2000 requests. After that, the average response time increased. When the number of requests reaches 10000 requests, the average response time is 1890 ms. With rise up the number of requests to 20000 requests, the average response time extremely increases to 19941ms. Through this massive number of requests, some requests fail while other requests take a long time to be sent. The result of this simulation shows that higher performance is achieved when the number of requests is low. While when the number of requests increases, the response time becomes unacceptable.

In order to obtain higher performance when sending a large number of requests, the system is expanded using cloud capabilities. Remote testing is applied to simulate the cloud environment. Fig. 10 shows how the response time improves when using remote distributed servers. Note that when the number of requests reaches 20000 requests, the average response time is less (14533 ms) than the time spent for the single local server.

Fig. 11 shows the performance of the system using the throughput metric for local and remote testing.

As shown in Fig. 11, the throughput increases when the number of requests increases using both local and remote testing. When the number of requests reaches 10000 requests, the throughput peaks to the highest point. However, the throughput using remote machines is higher than the local machine.

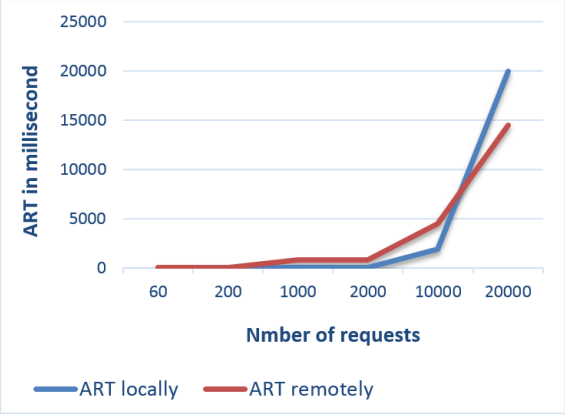

Fig. 10. Average Response Time of Local and Remote Machines.

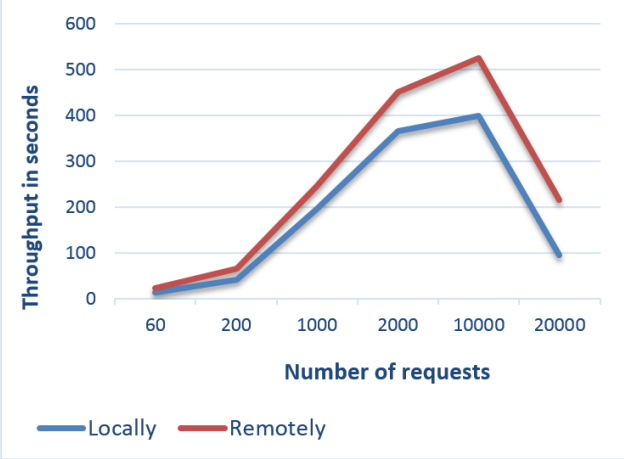

Fig. 11. Throughput Results for Local and Remote Machines.

VII. Conclusion

An integrated cloud-based framework is proposed to improve the security of data transmitted from wireless sensors networks. This paper aims to provide a secure environment for the sensed data. Therefore, the authentication scheme has implemented to ensure and validate sensors identity. In order to provide confidentiality and data integrity, encryption, and hashing mechanisms were used. The experimental results prove that the system performance is improved when sensor networks were integrated with the cloud-computing environment compared to local servers.

The framework proposed in this paper assumes that sensors in WSNs are fixed and their position coordinates are constant. In the future, features of portable sensors must be considered and investigated to enable the framework to protect the dataflow of the mobile sensors as well as static.

Further research is required to develop the framework in public and open source cloud services, and then measure network performance in terms of privacy, scalability, availability, and integrity. Furthermore, there is a need to intensify research to provide diverse methods and techniques for managing cloud resources and linking them to wireless sensor networks. Moreover, the proposed framework must be extended to supplement intrusion detection to improve the security level.

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Cancer Classification from DNA Microarray Data using mRMR and Artificial Neural Network

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***Abstract*—Cancer is the uncontrolled growth of abnormal cells in the body and is a major death cause nowadays. It is notable that cancer treatment is much easier in the initial stage rather than it outbreaks. DNA microarray based gene expression profiling has become efficient technique for cancer identification in early stage and a number of studies are available in this regard. Existing methods used different feature selection methods to select relevant genes and then employed distinct classifiers to identify cancer. This study considered information theoretic based minimum Redundancy Maximum Relevance (mRMR) method to select important genes and then employed artificial neural network (ANN) for cancer classification. Proposed mRMR-ANN method has been tested on a suite of benchmark datasets of various cancer. Experimental results revealed the proposed method as an effective method for cancer classification when performance compared with several related exiting methods.**

Keywords*—Cancer classification; gene expression data; minimum redundancy maximum relevance method; artificial neural network

I. Introduction

Cancer is the uncontrolled growth of abnormal cells in the body and is a major death cause nowadays. In a normal person without cancer, a healthy cell divides in a controlled way and produce new healthy cells. A cell with cancer grows out of control, divides and invades other tissues. All the daughter cells of a cancer cell are also cancerous. A cell changes its nature because mutation(s) have occurred in its genes. Cancer can affect anybody at any stage of life but people in older stage are more likely to be affected by cancer. The reason is that DNA may become damaged when old or may get worse due to the damage that happened in the past [1].

Cancer classification is the vital issue in DNA microarray gene expression profiling. Cancer may arise anywhere in the human body, and it names are remarked as body parts such as colon cancer, lung cancer, breast cancer. It is notable that cancer treatment is much easier in the initial stage rather than it outbreaks. DNA microarray based gene expression profiling has become an efficient technique for cancer identification in early stage. For classification, the first step is to recognize a small subset of genes which are primarily responsible for the disease [2]. And then look deep insight the selected genes for classification employing distinct classifiers.

A number of techniques have been investigated in past several years for cancer classification from DNA microarray gene expression data. A method used distinct classification method on selected genes with a particular feature selection technique. Xu et al. [3] investigated a method combining artificial neural network (ANN) and particle swarm optimization (PSO). Discrete binary PSO is employed for gene selection as well as dimensionality reduction. ANN is used to classify cancer from the selected genes. A large B-cell lymphoma dataset was considered to test the method.

Takahashi et al. [4] investigated a hybrid method of projective Adaptive Resonance Theory based ANN and boosted fuzzy classifier with SWEEP operator for cancer classification. They combined wrapper and filter approaches for gene selection. The method was tested on acute leukemia and brain tumor.

Ghorai et al. [2] investigated nonparallel plane proximal classifier (NPPC) ensemble method for cancer classification. At first, they trained a number of classifiers with mutual information criterion based selected genes. Finally, classifiers considered for the ensemble based on their performance on a validation set. The method was tested on colon and ALL/AML cancer.

Acharya et al. [5] employed Archived Multi objective Simulated Annealing (AMOSA), a multi objective optimization based clustering technique, for cancer classification. The developed technique was evaluated for three benchmark datasets: adult malignancy, brain tumor and small round blood cell tumors.

Arunkumar and Ramakrishnan [6] used extreme learning machines (ELMs) on microarray gene expression data for cancer classification. They extracted features using correlation coefficient prior to classification. The developed method was tested on several benchmark datasets: ALL/AML, CNS, Lung Cancer, Ovarian Cancer and Prostate Cancer.

Recently, Alshamlan et al. [7] investigated support vector machine (SVM) along with hybrid gene selection for cancer classification. At first, artificial bee colony (ABC), a swarm intelligence based optimization approach, was used in analyzing a microarray gene expression profile. Then, information theoretic based minimum Redundancy Maximum Relevance (mRMR) technique was combined with ABC for hybrid feature selection. Finally, SVM was used to classify cancer from features of the selected genes. They tested the algorithm on several gene expression microarray datasets including colon, leukemia, ALL/AML cancer. Rathore et al.

[8] investigated gene expressions based colon classification (GECC) using different feature selection methods including mRMR and ensemble of SVMs. A modified version of SVM, called Transductive SVM, is also investigated for cancer classification by Maulik et al. [9].

This study investigates ANN based cancer classification on selected genes from gene expression data. First, mRMR has been employed for gene selection and then ANN is used for cancer classification. Proposed mRMR-ANN has been tested on a suite of benchmark datasets of various cancers and outperformed existing methods while compared with those methods.

The outline of the remaining paper is as follows. Section II explains the proposed cancer classification from DNA microarray data using mRMR and ANN. Section III is for experimental studies which presents outcomes of the proposed method in solving benchmark datasets as well as compares with other related methods. At last, Section IV gives a brief conclusion of the paper.

II. Proposed Cancer Classification from DNA Microarray Data

There are three major steps in the proposed mRMR-ANN method: data preprocessing, gene selection by mRMR and finally classification with ANN. Fig. 1 shows the major steps of the proposed method and following subsections briefly describes the steps.

A. Preprocessing of Microarray Gene Expression Data

The presence of noise in the microarray gene expression data is common. Data can also be missing in some cases due to various stages of preparation. Together with small sample size, the classification task is challenging. That is why preprocessing is performed on the data owing to achieve better classification accuracy. On the other hand, data are normalized to transform all the data in same range which is essential for proper operation of classifiers.

In this study, K neighbor method is used to fill the missing data which is the extension of the nearest neighbor method. The method defines the missing value based on the values of K nearest neighbors from the testing sample [10]. Euclidean distance is commonly used to measure the distance between the data samples. Eq. (1) shows the distance between the two data points x_0 and x_i in the p dimensional space.

$$\text{Dist}(x_o, x_i) = (|x_{o1} - x_{i1}|^2 + |x_{o2} - x_{i2}|^2 + \cdots + |x_{op} - x_{ip}|^2)^{\frac{1}{2}} \quad (1)$$

Data normalization is a process in which data attributes within a data model are organized to increase the cohesion of entity types. The unity based normalization has been incorporated in this study where values of a particular attribute are transformed between 0 and 1. Eq. (2) is for the transformation.

$$X(t)_i = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}}, \quad (2)$$

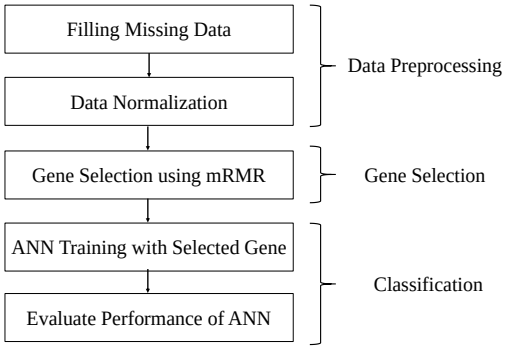

Fig. 1. Steps of Proposed mRMR-ANN Method for Cancer Classification.

where X_i and $X(t)_i$ are actual and transformed data points, respectively; X_{min} is the minima among all the data points; and X_{max} is the maxima among all the data points.

B. Gene Selection using Minimum Redundancy and Maximum Relevance (mRMR)

Selection of a small subset of appropriate genes from a lot of genes in microarray data is essential for precise cancer classification [11]. Although any feature selection method may be useful for this purpose, a conventional method typically ranks genes according to their differential expressions and picks the top-ranked genes for classification task. On the other hand, feature sets obtained through the minimum redundancy–maximum relevance framework might perform better classification than any rank based approach. In this regard, information theoretic based mRMR feature selection has been considered in this study which is frequently used to identify important and relevant features from the given data.

mRMR selects a feature subset that best characterizes the statistical property of a target classification variable, subject to the constraint that the selected features are marginally as similar to the classification variable as possible, but mutually as dissimilar to each other as possible. Eq. (3) shows the relevance of a feature set S for the class c which is defined by the average value of all mutual information (MI) values between the individual feature f_i and the class c.

$$\text{D}(\text{S}, \text{c}) = \frac{1}{|S|}\sum_{f_i \in S} I(f_i, c) \quad (3)$$

In the equation $I(.)$ indicates MI function. Eq. (4) shows the redundancy of all features in the set S which is the average value of all MI values between the features f_i and f_j.

$$R(S) = \frac{1}{|S|^2}\sum_{f_i, f_j \in S} I(f_i, f_j) \quad (4)$$

Finally, the mRMR criterion is shown in Eq. (5) which is a combination of two measures given in Eq. (3) and Eq. (4).

$$\text{mRMR} = \max\left[\frac{1}{|S|}\sum_{f_i \in S} I(f_i, c) - \frac{1}{|S|^2}\sum_{f_i, f_j \in S} I(f_i, f_j)\right] \quad (5)$$

In the equation $max(.)$ function is for combination of relevance and redundancy estimation. At a glance, mRMR is a filter method maintaining trade-off between relevancy and

redundancy. It ranks features according to criteria and provides top ranked user defined number of features. A demonstration of gene selection through mRMR is shown in Fig. 2. Among number of *F* genes, number of *K* (user defined number) genes has been selected using mRMR which are most informative for classification.

C. Classification using Artificial Neural Network (ANN)

ANN is designed with the goal of building intelligent machines to solve complex perceptual problems by mimicking special features biological neurons in the human brain [12]. The key elements of ANN are artificial neurons which have the information processing capability. Neurons are connected with other neurons though synaptic weights with a particular fashion for a particular task, such as data classification in this study. The synaptic weight values of an ANN are adjusted through a learning process to perform the specific task.

Fig. 3 displays the structure of ANN that employed in this study for cancer classification. The ANN has three different layers with feed forward architecture. The input layer is a set of input units (i.e., neurons), which receive the elements of feature vectors. Each input neuron is connected to the neurons of the hidden layer through different weight values. The hidden neurons are also fully connected to neurons of the output layer through another set of weight values. The output layer generates the response of ANN for a pattern placed to the input layer. The information given to the network is propagated from the input layer to the output layer through the hidden layer. And the weights $W_1, W_2, \ldots . W_n$ determine the influence of nodes of a layer in making decision to the next layer, i.e., hidden or output layer. For input vector $I = [I1, I2, \ldots . In \ ]^T$, each input is multiplied by the associated weight for summed input of a hidden layer neuron as of Eq. (6). The positive weights excite and the negative weights inhibit the node output.

$$Ih = I^T . W = I_1 W_1 + I_2 W_2 + \cdots + I_n W_n = \sum_{i=0}^{n} I_i W_i \qquad (6)$$

Finally, the output of the hidden neuron is calculated through activation function as of Eq. (7) where φ is the magnitude offset or bias term.

$$Oh = f(Ih - \varphi) \qquad (7)$$

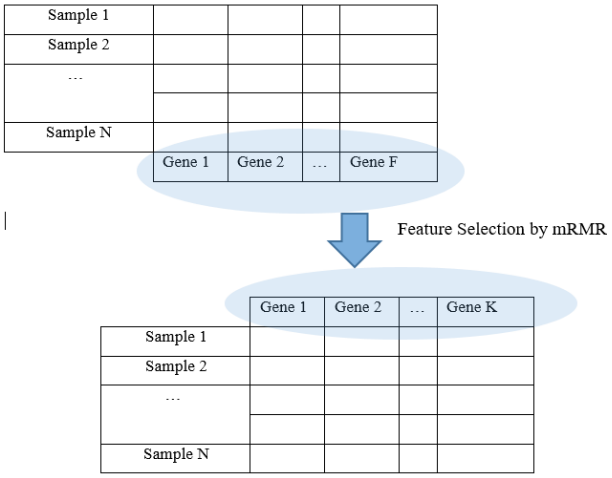

Fig. 2. Overview of Gene Selection using mRMR.

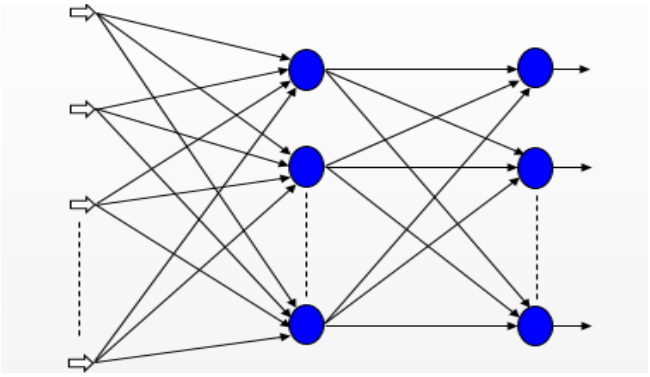

Fig. 3. Structure of Artificial Neural Network used in mRMR-ANN.

The output of the ANN is taken from the output layer and determines similar fashion of hidden layer using Eq. (6) and Eq. (7). For classification task, ANN needs to be trained to produce the desired input output mapping. In training, at first error is determined comparing actual output with desired output for training patterns and weight values are updated so that error is minimized. For *m* number of training data the squared error (*E*) can be given as:

$$E = \sum_{i=0}^{m} (t_i - o_i)^2 \qquad (8)$$

where *t* is the target/desired output and *o* is the calculated output from training data. The most popular training algorithm Back-Propagation (BP) is employed in this study for training the ANN [12].

III. Experimental Studies

This section experimentally investigates the efficacy of proposed mRMR-ANN method for cancer classification. A set of benchmark problems were chosen as a test bed and the performance of the mRMR-ANN compared with other popular methods. The experimental methodology were chosen carefully for fair comparison. An experimental analysis has also been presented for better understanding of the way of performance improvement in proposed method for cancer classification.

A. Benchmark Datasets

Four well studied microarray datasets have been considered for this study and those are Colon1, Colon2, ALL/AML and MLL. Colon1 dataset contains 62 samples and 2000 genes. There are 40 tumors and 22 normal samples. It is a binary class problem. Each of training and testing set contains 31 samples. Colon2 (i.e., Notterman Colon) dataset consists of 36 samples having 7,457 genes in each; out of which 18 samples are normal, and remaining 18 samples are malignant. ALL/AML dataset contains 72 samples of 7,129 genes; in which 47 samples are for acute lymphoblastic leukemia (ALL) and 25 samples are for acute myeloid leukemia (AML). Number of training and testing samples are 38 and 34, respectively. The mixed-lineage leukemia's (MLL) is a multiclass problem and dataset contains 72 samples of 12,533 genes. The subtypes are ALL (24 samples), AML (28 samples), and MLL (20 samples). Number of training and testing samples are 57 and 15, respectively. Table I shows summary of datasets with source reference.

TABLE. I. DESCRIPTION BENCHMARK MICROARRAY DATASETS

Dataset	Number of Classes	Total Genes	Total Samples
Colon1[13]	2	2,000	62
Colon2[14]	2	7,457	36
ALL/AML[13]	2	7,129	72
MLL[13]	3	12,582	72

B. Experimental Setup

Proposed mRMR-ANN has been implemented in Matlab R2015a. We have managed mRMR toolbox and its prerequisite of Mutual Information (MI) toolbox from MathWorks site. MI toolbox is kept in the same directory of the mRMR package. It is worth mentionable that Visual Studio is also necessary for functioning mRMR package because of many .cpp files in the package. We have run "makeosmex.m" file to execute .cpp extension file which are needed for computing MI. It was necessary to change log (2) to log (2.0) of all of the .cpp files. Inputs of the mRMR toolbox are *d* for all the features of dataset, *f* for the class labels of the dataset and *K* for the number of features to be selected. Output of the mRMR is the index number of the features in the dataset in the order of the relevance value. That means the most relevant feature is at first and the lowest relevant feature at the last position.

In ANN, sigmoid is used as activation function in Eq. (7) for hidden and output layers. Number of neurons at the input layer was number of features selected using mRMR. Number of neurons at the output layer was set according to the number of class of the problem. As an example, there will be three neurons in output layer to classify three cancer subtypes of MLL. On the other hand, number of neurons at the hidden layer is a user defined parameter and varied for better classification accuracy.

In order to measure the statistical significance of the proposed scheme, experiment has been repeated for 20 times on each setting for a particular problem. The average testing accuracy and their standard deviations are reported for each dataset. The experiments have been conducted on a PC with Windows 7 OS having system configuration Intel(R) Core(TM) i5-2520U CPU @ 2.5GHz with 8GB of RAM.

C. Experimental Results and Performance Comparison

This section first presents experimental results of proposed mRMR-ANN on each individual dataset for different settings and then compares outcome of it with prominent exiting methods. The number of selected genes (GN) through mRMR varied from 100 to 500. On the other hand, the number of hidden neuron (HN) of ANN varied from 20 to 200. ANN was trained over 500 iterations. The feature selection using mRMR and training with ANN were performed with training set and test set was reserved to check system performance on unseen data. Tables II to V show testing set classification accuracy (TSCA) for Colon1, Colon2, ALL/AML and MLL datasets for each individual setting. The results presented in the tables are the outcome of 20 independent runs of ANN for each setting.

TABLE. II. TEST SET CLASSIFICATION ACCURACY IN PERCENTAGE (%) FOR COLON1 CANCER

Num. of GN	Num. of HN	Best TSCA	Worst TSCA	Avg. TSCA	SD of Avg.
100	20	83.9	83.9	83.9	0
	50	83.9	83.9	83.9	0
	100	83.9	83.9	83.9	0
	200	83.9	83.9	83.9	0
200	20	83.9	83.9	83.9	0
	50	83.9	83.9	83.9	0
	100	83.9	83.9	83.9	0
	200	83.9	83.9	83.9	0
300	20	83.9	83.9	83.9	0
	50	83.9	83.9	83.9	0
	100	83.9	83.9	83.9	0
	200	83.9	83.9	83.9	0
400	20	83.9	83.9	83.9	0
	50	83.9	83.9	83.9	0
	100	83.9	83.9	83.9	0
	200	83.9	83.9	83.9	0
500	20	83.9	83.9	83.9	0
	50	83.9	83.9	83.9	0
	100	83.9	83.9	83.9	0
	200	**87.1**	**87.1**	**87.1**	**0**

TABLE. III. TEST SET CLASSIFICATION ACCURACY IN PERCENTAGE (%) FOR COLON2 CANCER

Num. of GN	Num. of HN	Best TSCA	Worst TSCA	Avg. TSCA	SD of Avg.
100	20	100	94.4	99.7	0.01
	50	88.9	88.9	88.9	0
	100	88.9	88.9	88.9	0
	200	94.4	88.9	89.2	0.01
200	20	100	100	100	0
	50	100	100	100	0
	100	100	100	100	0
	200	100	94.4	99.7	0.01
300	20	94.4	94.4	94.4	0
	50	100	94.4	99.2	0.02
	100	94.4	94.4	94.4	0
	200	100	100	100	0
400	20	100	94.4	99.7	0.01
	50	94.4	94.4	94.4	0
	100	100	100	100	0
	200	94.4	94.4	94.4	0
500	20	94.4	94.4	94.4	0
	50	100	100	100	0
	100	94.4	94.4	94.4	0
	200	**100**	**100**	**100**	**0**

TABLE. IV. TEST SET CLASSIFICATION ACCURACY IN PERCENTAGE (%) FOR ALL/AML CANCER

Num. of GN	Num. of HN	Best TSCA	Worst TSCA	Avg. TSCA	SD of Avg.
100	20	91.2	85.3	85.9	0.018
	50	88.2	88.2	88.2	0.000
	100	85.3	82.4	85.1	0.007
	200	91.2	85.3	87.5	0.021
200	20	94.1	91.2	91.5	0.009
	50	94.1	91.2	91.3	0.007
	100	97.1	88.2	91.1	0.017
	200	94.1	88.2	89.3	0.017
300	20	94.1	76.5	85.4	0.031
	50	97.1	94.1	94.3	0.007
	100	97.1	88.2	95.1	0.024
	200	91.2	82.4	90.3	0.027
400	20	97.1	82.4	91.3	0.031
	50	76.5	50	60.4	0.053
	100	97.1	85.3	92.8	0.029
	200	76.1	85.3	91.2	0.021
500	20	94.1	70.6	89.9	0.054
	50	79.4	61.8	64.6	0.053
	100	85.3	73.5	76.5	0.029
	200	**97.1**	**64.7**	**92.4**	**0.079**

It is observed from Table II for Colon1 cancer that GN values from 100 to 400 the system shows invariant result and for GN=500 and HN=200 system shows best TSCA of 87.1%. On the other hand, result varies for Colon2 cancer due to parameter setting as it is seen in Table III. The reasons for such observation presume that Colon1 contains less number of GN and Colon2 contains less number of samples with respect to other datasets. Among the four datasets, mRMR-ANN achieved 100 % TSCA for Colon2 and MLL datasets. It is observed from the tables that mRMR-ANN performed relatively better for larger values of GN and HN in comparison of smaller values of those. As an example, for ALL/AML cancer (Table IV) average TSCA was 85.9% for GN=100 and HN=20; for the same problem average TSCA was 95.1% for GN=300 and HN=100. It is logical for worse TSCA with less GN because some genes may be missed by mRMR looking training data. Finally, proposed mRMR-ANN seems to be a suitable method for cancer classification showing good TSCA.

Table VI shows the numerical comparative results of the mRMR-ANN and other existing related methods. The result presented for the proposed method is the best TSCA values from Tables II to V. On the other hand, the results of other methods are the reported results in referred papers. An existing method tested on one or two cancer datasets and therefore others are marked as '-' meaning that results are not available. NPPC method achieved TSCA of 84.02% and 96.46% for Colon1 and ALL/AML datasets. For both the datasets, mRMR-ANN outperformed NPPC showing TSCA of 87.10% and 97.10%, respectively. ELM was also tested for ALL/AML dataset but achieved worst performance i.e., 93.10%. Recent method GECC tested for Colon2 dataset and achieved TSCA 97.22%; and TSVM tested for MLL dataset and achieved TSCA 88.80%. On the other hand, for both Colon2 and MLL datasets proposed mRMR-ANN achieved 100% classification accuracy. Therefore, proposed method is found relatively better than existing methods for cancer classification.

The experimental results presented in Tables II to V were for fixed number of training iteration of ANN with different GN and HN values. Therefore, it is interesting to observe effect of training iteration on the performance of proposed mRMR-ANN and Fig. 4 shows the graphical representation of TSCA with respect to iteration for the four datasets. Training iteration was varied from 10 to 1000 while number of mRMR selected genes and hidden neurons of ANN were fixed at 100. From the figure it is observed that TSCA was very low for less number of iteration and improved gradually. As an example, for Colon1 dataset, TSCA was 48.39% at 10 iteration and improved up to 83.87% at 100 iteration. It is notable from the figure that after 400 iteration no improvement has been observed for any dataset. It indicates the experimental results presented for 500 fixed iteration is appropriate.

TABLE. V. TEST SET CLASSIFICATION ACCURACY IN PERCENTAGE (%) FOR MLL CANCER

Num. of GN	Num. of HN	Best TSCA	Worst TSCA	Avg. TSCA	SD of Avg.
100	20	86.7	86.7	86.7	0
	50	86.7	86.7	86.7	0
	100	86.7	86.7	86.7	0
	200	86.7	86.7	86.7	0
200	20	86.7	86.7	86.7	0
	50	86.7	86.7	86.7	0
	100	93.3	93.3	93.3	0
	200	86.7	86.7	86.7	0
300	20	86.7	86.7	86.7	0
	50	86.7	86.7	86.7	0
	100	93.3	93.3	93.3	0
	200	86.7	86.7	86.7	0
400	20	86.7	86.7	86.7	0
	50	**100**	**100**	**100**	**0**
	100	86.7	86.7	86.7	0
	200	86.7	86.7	86.7	0
500	20	93.3	93.3	93.3	0
	50	93.3	93.3	93.3	0
	100	93.3	93.3	93.3	0
	200	93.3	93.3	93.3	0

TABLE. VI. CLASSIFICATION ACCURACY (TSCA IN %) COMPARISON OF MRMR-ANN WITH PROMINENT EXISTING METHODS

Dataset	NPPC [2]	ELM [6]	GECC [8]	TSVM [9]	Proposed mRMR-ANN
Colon1	84.02	-	-	-	87.10
Colon2	-	-	97.22	-	100
ALL/AML	96.46	93.10	-	-	97.10
MLL	-	-	-	88.80	100

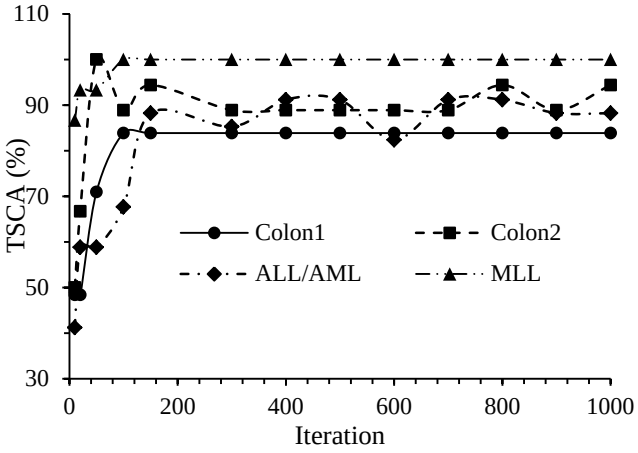

Fig. 4. Test Set Classification Accuracy (TSCA) vs. Iteration.

IV. Conclusions

Cancer treatment is much easier in the initial stage and DNA microarray based gene expression profiling has become an efficient technique for it. The gene expression is a very high dimensional data but relatively small number of genes are responsible for cancer; and therefore, classification looking on a subset of genes' expression (selecting through a suitable feature selection method) is a common way. In this study, information theoretic based mRMR has been considered for selecting cancer related genes and then ANN has been employed for classification. The proposed mRMR-ANN method first normalizes the gene expression data to employ mRMR and found effective to achieve better result. Although a few methods used mRMR in cancer classification, ANN with mRMR of this study has outperformed other methods while tested on several benchmark cancer datasets.

There are several future potential directions that follow from this study. Cancer classification is a sensitive task and its high accuracy is necessary. Proposed mRMR-ANN has shown to classify all the test samples correctly for two problems and it is remained an open challenge for other problems. This study considered maximum 500 genes in classification, more genes might give better outcome. On the other hand, the use of ensemble of ANNs instead of single ANN might be a good choice to improve classification performance.

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A Convolutional Neural Network for Automatic Identification and Classification of Fall Army Worm Moth

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***Abstract*—To combat the problem caused by the Fall Army Worm in the country there is a need to come up with robust early warning and monitoring systems as the current manual system is labor intensive and time consuming. The automation of the identification and classification of the insect is one of the novel methods that can be undertaken. Therefore this paper presents the results of training a Convolutional Neural Network model using Google's Tensorflow Deep Learning Framework for the identification and classification of the Fall Army worm moth. Due to lack of enough training dataset and good computing power, we used transfer learning, which is the process of reusing a model trained on one task as a starting point for a model on a second task. Googles pre-trained InceptionV3 model was used as the underlying model. Data was collected from four sources namely the field, Lab setup, by crawling the internet and using Data Augmentation. We Present results of the best three trials in terms of training accuracy after several attempts to get the best metrics in terms of learning rate and training steps. The best model gave a prediction average accuracy of 82% and a 32% average prediction accuracy on false positives. The results shows that it is possible to automate the identification and classification of the Fall Army worm Moth using Convolutional Neural Networks.**

***Keywords*—Augmentation; convolutional neural networks; classification; fall army worm; machine learning; tensorflow; transfer learning**

I. Introduction

The Fall Army Worm possesses unique characteristics that make it a more devastating pest than other crop pests. It can spread quickly over a large geographical area, it can persist throughout the year meaning it is also able to affect irrigated plants and it can feed on over 80 different plant species [1][2][3]. The characteristics of the Fall Army worm enable it to cause massive damage to crops such as maize threatening the food security of countries where maize is the staple food. Its impact has been felt at national and household level [3]. Owing to its unique characteristics and the destructive nature of the FAW pest, the need to put up quick and proper monitoring systems of the insect can never be over emphasized. Currently the monitoring process of the insect being applied is the traditional pest monitoring process of manual observations and data collection and the use of Pheromone traps. The manual process is labor intensive, time consuming, costly as it requires the engagement of field experts and requires one to count the insect for data collection which is likely to give false data [4][5]. Pheromone traps have proven to be effective in the monitoring of Pests in the field but still requires manual counting of the insect for data collection which is usually after weeks [6]. Delay in Pest data collection means a delay by would be stakeholders to apply appropriate counter measures to the Pest. In this regard, the use of computer based automated insect monitoring and classification is the solution [7] [8]. Machine learning is one of the technologies that are being applied in Agriculture in what is termed as Smart Farming to solve various challenges that the field faces. Its Application in Agriculture include but not limited to plant disease detection, farming area classification, plant recognition, fruit counting, Soil and vegetation mapping, Pest detection and management [9][10]. One of the problems in agriculture where machine learning can be applied also is the automation of Pest monitoring which requires in most cases the capture of images of live insects in the field. Deep learning is a recent branch of machine learning that constitutes modern techniques for image processing and recent studies show that it has successfully been applied in agriculture and has achieved unprecedented results [11]. Therefore in this paper we present the results of training a Convolutional Neural network model for identification and classification of Fall Army Worm. Due to lack of enough dataset and lack of computing power, we used data augmentation to supplement the dataset and transfer learning using the Google inceptionV3 model. The paper is divided into literature review, materials and methods, results, discussions and conclusion.

II. Literature Review

To supplement the results and get a broader understanding of the concepts of Deep learning and Convolutional Neural Networks, relevant literature was reviewed.

A. Convolutional Neural Network

Convolutional Neural Networks is the novel and most popular machine learning technology that has successfully been applied in computer vision and image classification. They are made up of a class of feedforward Artificial Neural Networks sharing weights [11]. The basic idea behind CNN is the local understanding of an image. They combine three architectural ideas, local understanding of the image, shared

weights and subsampling to ensure some degree of shift and distortion invariance [12]. The main architectural benefit of CNN is few parameters which in turn improve the learning time and a reduction in the amount of training data however enough training data increases the prediction accuracy. They are made up of Convolutional layers which act as feature extractors from input images, pooling layers which perform sampling operations on the dimensions of the input image thereby reducing the dimensions and fully connected layers which acts as classifiers by using the high level features learned [11][12][13][14]. Fig. 1 shows a typical Convolutional Neural Network Architecture where several convolutions are applied creating different representations of training datasets.

Traditionally classification problems were solved by first manually extracting image features and then serving the features as input to a trainable classifier which meant that the accuracy of the task was dependent on the extracted features. This limited the use of the manual approach [11][14]. Deep learning algorithms particularly Convolutional Neural Networks have proved to overcome the challenges of manual feature extraction but the increase in the complexity and size of the networks meant that a huge amount of training dataset is required which brings in the need for good computing power [15]. Training a good CNN from scratch requires a huge dataset and good computational resources. Fortunately one can use a technique called transfer learning to solve a classification problem. Transfer learning is the process of using a CNN that has been trained on a generic image classification task to solve a more specialized classification task. It is the use of a pre-trained model on another task as the starting point to another model of a different task. It falls into two categories: (i) Feature extraction which is the extraction of meaningful features from new samples by using representations learned by the pre-trained model in the previous work. This involves the training of a Top layer (classification layer) which is usually a Softmax function which is the output function of the last layer in neural networks whose purpose is to turn the score produced by the network into values that can be interpreted by humans. The Softmax function is defined as follows [15].

The function is given by: $\sigma : R^n \rightarrow int(\Delta^{n-1})$

$$\sigma(z)=\frac{\exp(\lambda Z_1)}{\sum_{j=1}^{n}\exp(\lambda Z_j)}\ , 1\leq i \leq n \qquad (1)$$

When $\lambda = 1$, (1) is called the standard Softmax function.

(ii) Fine tuning which is trying to unfreeze a few layers from the pre-trained model and training them together with the new classification layer [16][17][18]. Fig. 2 shows an example of transfer learning architecture.

There exists a number of pre-trained models which have successfully been used in recent years in transfer learning to solve classification problems such as ResNet50, inceptionV3, MobileNetV3 and VGG16. The models have been trained on huge datasets giving them the ability to generalize to new datasets when used in transfer learning [15]. Some of the models such as the InceptioV3 (Fig. 3) have been used in many image classification problems and have shown to have attained accuracies greater than 78.1% [19] [20].

The inceptionV3 was developed and trained using a Deep Learning framework called Tensorflow which provides several libraries for numerical computations [17][20][21][22]. In addition, Tensorflow provides a web based dashboard for visualizing the ongoing training called Tensorboard and makes it easy to deploy the trained model using what is called Tensorflow serving. In this research we are using the Feature extraction part of transfer learning since the inceptionV3 model has been trained on a large dataset enough for it to generalize to our datasets. of course Fine tuning will be the best option to get better and higher accuracies.

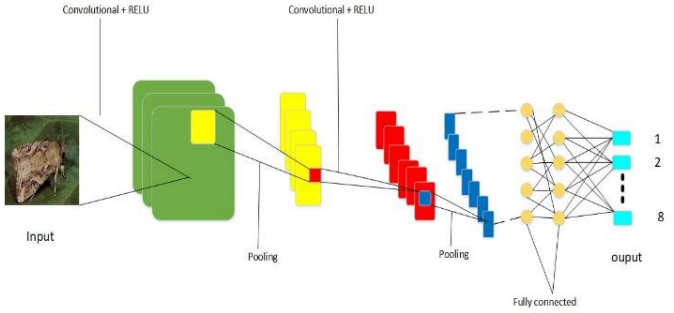

Fig. 1. Typical CNN Architecture.

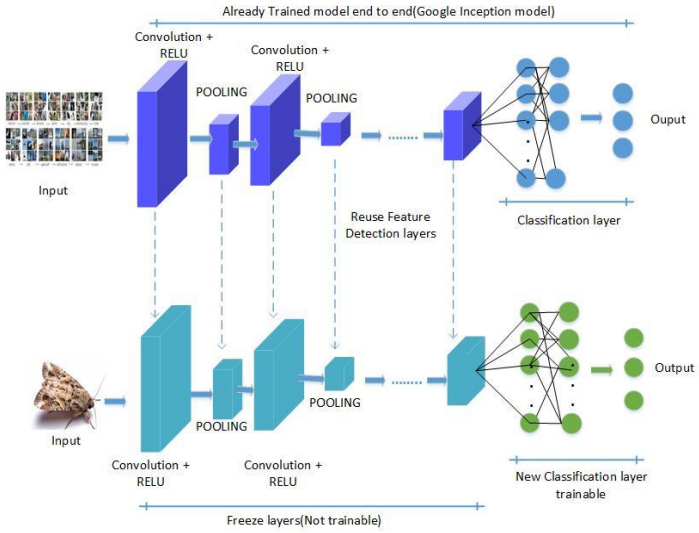

Fig. 2. Typical CNN Architecture.

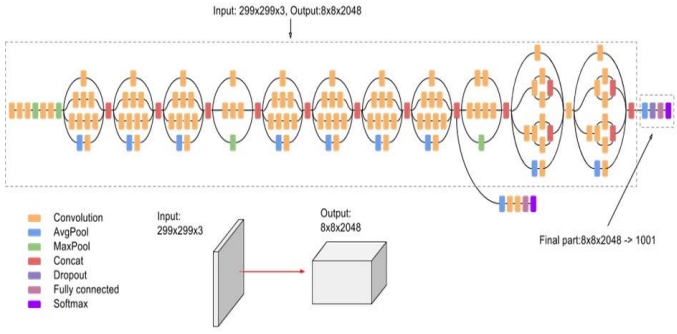

Fig. 3. InceptionV3 Architecture.

B. CNN Application in Classification Problems

The success that Convolutional Neural Networks have found in the classification problem domain can be attributed to a number of factors which may include but not limited to automatic feature detection, higher accuracies obtained, availability of good computing resources such as GPUs and availability of large datasets. Convolutional Neural Networks have successfully been used in many areas of agriculture in what is termed as Smart Farming. Some of the areas where CNNs have been used in agriculture include crop type classification, plant disease detection and recognition and so on [11]. In [18], the authors developed a model for predicting skin cancer cells by image classification using CNN and obtained more than 85% prediction accuracy and [23] tried to automate the classification of ovarian cancer using CNN to aid pathologists in cancer diagnosis. They used CNN based on AlexNet to predict ovarian cancer from cytological images. They obtained an accuracy of 78.20% by using augmented datasets. [24] Presented a self-operating stretcher developed using CNN transfer learning that solves the problem of transporting patients from long distances or short distances. The stretcher is trained to detect and identify the objects in its path. Authors in [17, 23, 24] showed that CNN are also applicable in medicine and are helping to solve many challenges that the field faces. [25] Applied CNN to the automatic classification of mosquitoes in the field. They used 4,056 mosquito images as training dataset and obtained classification accuracy of 82%. [26] Presented a method and the performance of the model for detection and classification of insects on sticky traps using CNN and obtained an average accuracy of 87.4%. Author in [27] applied CNNs in the identification of bacteria using 3D microscopy datasets. They tried to use CNNs to distinguish bacteria from non-bacterial objects from images obtained from zebrafish intestines using a microscopy. They deducted that CNNs are as accurate as human experts. The application of CNNs is broader and wide and results have shown that they are as accurate as they can be provided the correct training is done.

III. Materials and Methods

A. Ethical Statement

The field data collection did not involve any species that is considered endangered hence no permits were required for us to collect data from the field.

B. Data Collection

Data was collected from 4 sources namely the field, Lab setup, and Internet crawling and data augmentation. Field data was collected from the Zambia Agriculture Research Institute research farms and taking photos of identified male FAW moth using a Cannon PowerShot SX430 IS Camera. With the aid of entomologists who are experts in FAW moth identification, we were able to obtain data from pheromone traps and from maize plants as FAW favors maize fields and most of them were resting in the fields as they are active during the night due to their delicate nature when exposed to the sun. In addition to taking photos and to supplement the collected data, we collected live FAW moths in beakers and set them up in a lab kind of environment. Since we will be dealing with the identification of live moths we tried as much as possible to take photos of live moths strategically positioned in the pheromone trap or in the beaker though we also had images of dead FAW moths which made it easier to strategically position them. The collected data was not enough so we mixed the data from the field and lab setup with Internet images of FAW moths. We manually collected images from the internet by searching in the browser to make sure that the FAW moth images resemble the field images in terms of features and make sure that the collected image contains only the FAW moth as shown by Fig. 4.

The data collected from the field, Lab setup and Internet was not enough to give us confidence that we will train a reasonable model. To get a dataset that gave us comfort in terms of model training and testing, we used data augmentation, in fact 60% of the dataset came from augmentation. We used a python script which generated atleast 8 (67x65) more images as shown by Fig. 5 from an image by applying random cropping, random flipping, rotation using a rotation range of 40 degrees and random zoom.

Our focus was mainly on the automated identification of FAW moth but Convolutional neural networks requires that there are atleast two classes to perform a classification problem properly therefore we used other insects and moths which we referred to us false positives. There was no big reason that compiled us to use certain insects as the false positive class because it is hoped that the lure used in the traps which will act as the source of images will attract only FAW moth and majority of the insects attracted are FAW male moths. We therefore included a variety of insects with majority of them being moths which included but not limited to African bollworm moth, African Fly, Mosquitoes, Corn Borer moth, cutworm moths, stalkborer moths, stem borer moths and so on. The images of other insects were all collected by crawling the internet and we applied data augmentation to increase the dataset. We wanted to see how the model will perform if it was trained on unclear images (pixilated at 10pixels) and tested on clear actual FAW images, so we created another dataset of blurred FAW images from the dataset we made using a python script.

Fig. 4. Images Collected from the Field, Lab Setup and Internet Respectively.

Fig. 5. Sample of Image Augmentation with the First One being the Original.

C. Data Selection and Distribution

Once the dataset was structured, training, validation and testing images were determined. Before doing data augmentation, we selected 30 FAW images and 15 false positive images as test datasets. We selected mostly original clear unaugmented images as test images. The selected test images were not used in the training to avoid overfitting and were used only after the model was trained. We divided the test datasets into three parts of 15 images each namely Augmented, Actual Clear FAW and False Positives. The test Augmented images were a mixture of pixilated (at 5 pixels) images and randomly rotated, random vertically flipped and rescaled images. A total of 750 FAW images and 400 false positive images were generated using the process described in data collection section when data augmentation was done. Out of 750 FAW images, 10% were used as validation images since Tensorflow uses auto validation and the rest of the images were used as training dataset. From 400 false positives, 10% were used as validation dataset aswell and the rest as training dataset. Table I shows the division of the dataset.

D. CNN Model Training and Testing

We used Transfer learning to train a Softmax layer on Top of the InceptionV3 model trained on the imageNet dataset which is a dataset of about 15 million labeled high resolution images with around 22, 000 categories [20]. The inception model gives high accuracy but is slower during training and looking at the dataset we had, it was the ideal choice. The training of the model was done on a Corei5 machine with 4GB RAM and 1TB hard disk. The operating system used was Ubuntu 18.04. We created a python virtual environment were all the dependents were installed to avoid conflicting dependent versions. Before training, Convolutional Neural Network algorithms demands defining parameters before training as they are likely to influence the classification results therefore we left all the parameters such as dropout, batch size, image crop and so on as they are defined in the pre-trained model and only altered the learning rate and training steps. We ran 8 trials and in each trial changing the learning rate and the number of training steps (epochs) in order to get the best and tested the models. From the 8 trials we got the best two trials which gave the best test accuracy and error rate. Out of the two selected trials, we picked the parameters of the model that gave the best results after being tested on test data and trained a pixilated FAW images model. The purpose of the pixilated trial was to test how the model will perform if trained on pixilated (blurred) images and tested on clear, augmented and false positive images. after training the Pixilated FAW images model, we ran the test data using the model and recorded the results and at the end we had three trials, namely, i) Clear FAW images, 0.01 learning rate, and 1500 training steps; ii) Clear FAW images, 0.001 learning rate and 5500 training steps; and iii) Pixilated (blurred) FAW images at 10 pixels, 0.01 learning rate and 1500 training steps and ranked them according to the best performing model in terms of identifying the actual and augmented FAW images and false positives.

TABLE. I. DATA DISTRIBUTION

Category	Total	Training	Validation	Test
FAW	780	645	75	30
False positives	400	360	40	15

IV. RESULTS

After a couple of trials to try and get the best learning rate and training steps, we finally got two of the best learning rates, 0.01 using 1500 training steps and 0.001 using 5500 training steps. We used 0.01 learning rate with 1500 steps to train another model using pixilated FAW moth images just to test the performance of the model when tested with clear images. We have grouped the results of the three tests into groups according to the model that performed better on all categories of test data.

A. Clear Faw Images, 0.01 Learning Rate, and 1500 Training Steps

Classification accuracies of round one model on all the three test categories are given by Table II. The model gave an average classification accuracy of 82% on actual clear FAW images, an average of 70.84% on augmented images and an average accuracy of 32.1% on false positives. The predication accuracy was low in augmented images due to the fact that the images were distorted with most of them being pixilated. The model performed well in false positives which were images of other insects not FAW and were not used in the training dataset. Fig. 6 and 7 shows the Tensorboard training graphs and Fig. 8 shows the prediction accuracies.

TABLE. II. ROUND 1 PREDICTION ACCURACIES

#	Augmented %	Actual %	False positives %
1	97.8	90.1	54.7
2	84.3	98.2	49.8
3	97.6	97.6	24.1
4	19	90.9	47.5
5	40	99.4	42.9
6	95.8	93.7	80
7	31.6	51.7	45
8	89.4	94.2	0.1
9	77.9	94.4	71.1
10	47	43.5	0.2
11	64.1	74.8	7.4
12	87.9	86.2	1.2
13	79.6	69.8	52.7
14	92.6	47.9	1.3
15	58	97.5	2.7

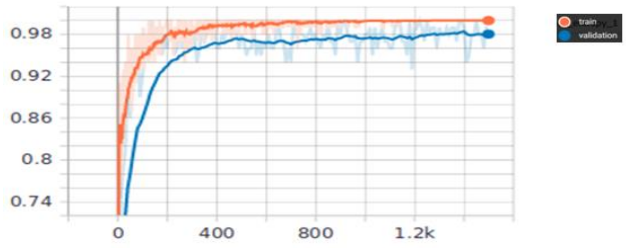

Fig. 6. Round 1 Training Accuracy.

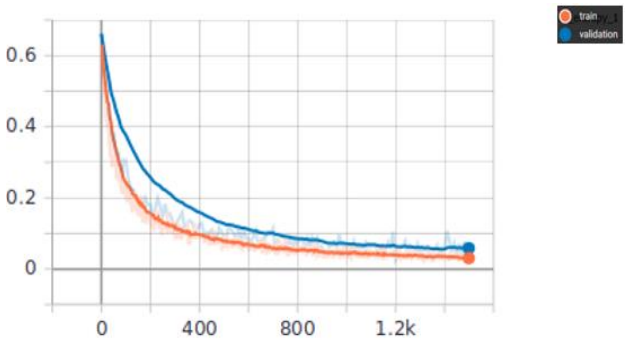

Fig. 7. Round 1 Cross Entropy.

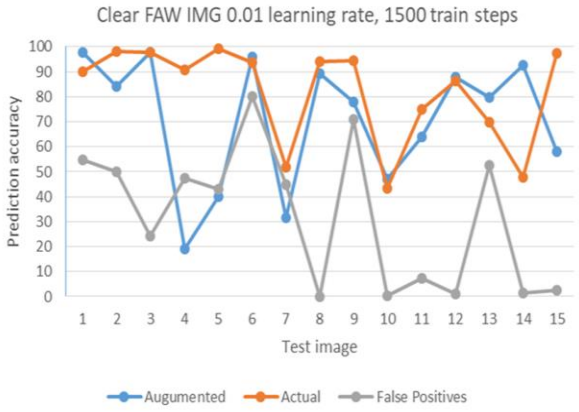

Fig. 8. Round 1 Prediction Accuracy.

B. *Clear Faw Images, 0.001 Learning Rate, and 5500 Training Steps*

Table III shows the prediction accuracies of the second round model and gave average prediction accuracies of 75.8% on actual clear FAW images, 76% on augmented images and 48.8% on false positives. The drop in the accuracies on actual images might be attributed to the rate at which the model was learning as we reduced the learning rate. Fig. 9 and 10 shows the Tensorboard training graphs and Fig. 11 shows the prediction accuracies.

C. *Pixilated (Blurred) Faw Images at 10 Pixels, 0.01 Learning Rate and 1500 Training Steps*

Table IV shows the prediction accuracies of the third round model. The model performed badly in all categories when tested on all three test categories as shown in Fig. 12.

TABLE. III. ROUND 2 PREDICTION ACCURACIES

#	Augmented %	Actual %	False positives %
1	95.8	90.1	5.2
2	80.9	96.3	33.8
3	95.2	67.5	20
4	12.2	74.2	19.1
5	41.1	91	4
6	86.5	91.7	2.9
7	73.5	50.3	93.4
8	77.5	89	46.8
9	80.9	98.7	94.5
10	85	17.9	47.8
11	77.5	89.2	94
12	89	95.7	56.7
13	93.6	39.3	73.5
14	95.2	50	87.4
15	61	96.7	53.1

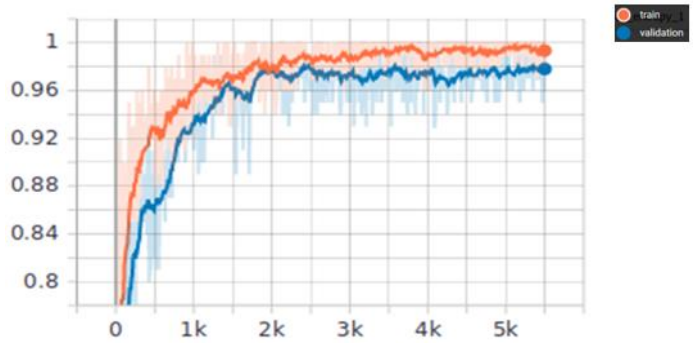

Fig. 9. Round 2 Training Accuracy.

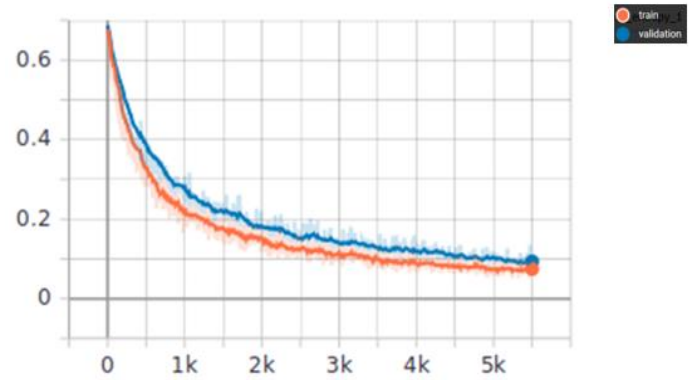

Fig. 10. Round 2 Cross Entropy.

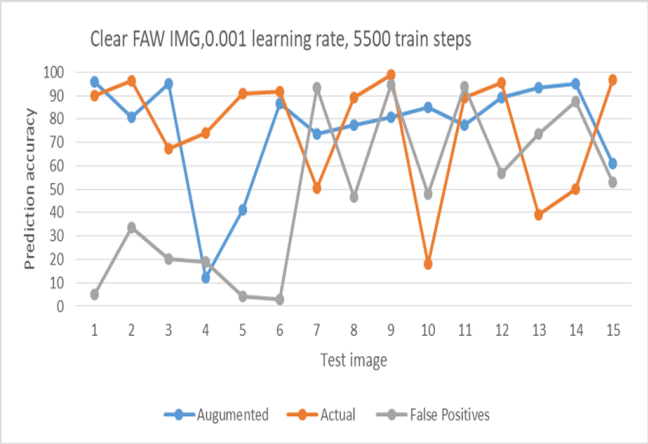

Fig. 11. Round 2 Prediction Accuracy.

TABLE. IV. ROUND 3 PREDICTION ACCURACIES

#	Augmented %	Actual %	False positives %
1	94.3	17	93.2
2	3.9	7.8	99.7
3	66	1.6	99.6
4	8.6	62.6	1.2
5	13.3	9.2	1.9
6	99.1	28.5	9.7
7	12.6	11.2	93
8	25	1.2	53
9	9.6	1.3	14.8
10	53.9	16	42
11	99.8	9.4	100
12	40.7	0.3	100
13	6.5	11.8	97.5
14	39.3	12.6	0.5
15	51	14.8	0.7

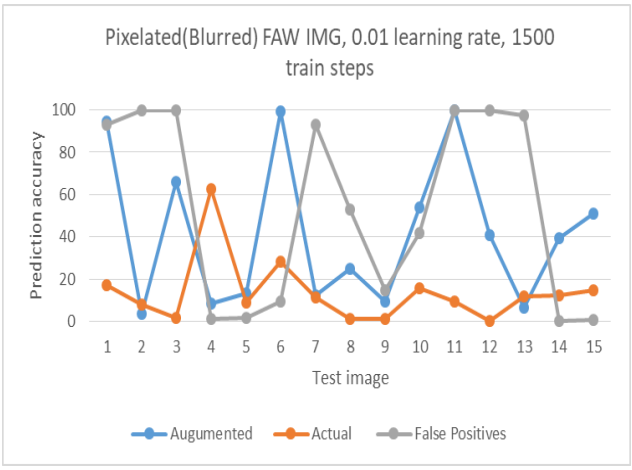

Fig. 12. Round 3 Prediction Accuracy.

V. DISCUSSION

We tested a model for the automatic identification and classification of Fall Army worm using convolutional neural networks. The major challenges we faced in the study included but not limited to; the size of test data which was fairly little and we had to rely on data augmentation which most likely affected results since to train a good CNN a good amount of data is needed. The lab setup was a bit challenging when dealing with live moth as it was near impossible to place them strategically hence we relied on the dead ones most of the time. The other challenge was the lack of previous work on Fall Army Worm using CNN which could have provided us with an opportunity to build on what others have done. Lack of good computing power meant that we had to use a pretrained model instead of building our own from scratch which would have given us an opportunity to fine tune the network in a way that suits our needs and hence get better results.

As CNNs requires a fairly large amounts of data to train a good recognition model and we had little data, we applied transfer learning using the inceptionV3 pre-trained model. The prediction accuracies were largely affected by little training data. After several trials the results of round one gave a better prediction accuracy (82%) which could greatly be attributed to the higher learning rate. Many improvements can be done to try and improve the prediction accuracies such as using fine tuning instead of feature extraction transfer learning and unfreeze a few feature extraction layers of the inception model and train them together with our new classification layer. We could also try and increase the training data set by collecting more images from the field and the internet and applying augmentation even though augmentation does not guarantee that the model will learn any new features. The other improvements we could use is the removal of noise from the current dataset such as removing the entire background from images. Another factor to consider would be the introduction of other insect classes because in the presented results our focus was on FAW only hence we just introduced a false positive class and added insects which are likely to be attracted to the FAW pheromone hormone.

VI. CONCLUSION

In this paper we investigated the use of Convolutional Neural Networks to identify and classify Fall Army Worm moth. We have presented results of three models built using transfer learning and the best model gave an average prediction accuracy of 82%. This is an ongoing research and future work may include but not limited to; increasing and cleaning the dataset by continuing to collect more from the field and the internet, trying the feature extraction of transfer learning and use the extracted features in a support vector machine and see how the results compare with the results of this paper, apart from the inceptionV3 we intend on trying out other pre-trained models such as mobileNet and compare the results with that of inceptionV3. The other work that will attempt to do is the use of more advanced deep learning algorithms and see how the results compares. The results show that it is possible to build a CNN model for FAW classification hence we develop a monitoring tool based on the model to achieve near real-time monitoring of the Fall Army worm.

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Communication and Computation Aware Task Scheduling Framework Toward Exascale Computing

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***Abstract*—The race for Exascale Computing has naturally led computer architecture to transit from the multicore era and into the heterogeneous era. Exascale Computing within the heterogenous environment necessarily use the best-fit scheduling and resource utilization improvement. Task scheduling is the main critical aspect in managing the challenges of Exascale in the heterogenous computing environment. In this paper, a Communication and Computation Aware task scheduler framework (CCATSF) is introduced. The CCATSF framework consists of four parts; the first of which is the resource monitor, the second is the resources manager, the third is the task scheduler and the fourth is the dispatcher. The framework is based on a new hybrid task scheduling algorithm for a heterogenous computing environment. Our results are based on the random job generator that we implemented, and they indicate that the CCATSF framework, based on the proposed dynamic variant heterogenous early finish time (DVR-HEFT) algorithm is able to reduce the scheduler's makespan and increase the efficiency without increasing the algorithm's time complicity.**

Keywords*—Exascale computing; resource utilization; hybrid task scheduling; heterogeneous computing environment; task scheduler framework

I. INTRODUCTION

Scientific research these days requires the use of huge computation-intensive applications, which increasingly demand efficient and on-time executing high-performance computing systems (HPCS). The next generation of HPCS, in the near future, is Exascale Computing. Recently, the Tianhe-3 prototype that can perform at one exaFLOPS has completed acceptance testing for China's Ministry of Science and Technology [1]. Exascale era is clearly coming soon. Computing at exascale level and beyond involves many challenges; the main ones of which are scalability and heterogeneity. Programs will need to control billions of threads, running on different types of cores with different styles of architecture. This in turn will cause different parts of the system to run at different speeds. Applications will need to reduce communication and memory usage relative to the amount of computing; failures will be more frequent, possibly including silent errors. In these situations, good power management and error handling will become essential. Generally, to successfully achieve an exaflopic cluster, every aspect should be optimized, from hardware to execution instructions and tasks, all parts of these extraordinary systems must be improved [2].

Fig. 1 illustrates the roadmap for Exascale Computing. In 2013, Titan in the USA and Tsubame KFC Tokyo Tech were the biggest supercomputers. They were 2.5GFlops/W and 4.5GFlops/W, respectively [3] in time they both use heterogeneous computing, as both were utilizing K20 GPU, but Tsubame KFC have several advantages on Titan.

One of which is changing the ratio CPU/ GPU, as energy consumption mostly goes more to the GPU and less to the CPU. Therefore, such techniques that leverage the available resources are desired. Thus, one way of thinking to reach exascale is the improvements that are 20PFlops, 10Wand 107threads so as by 2023, it will have been duplicated 50times to get 1000GFlops besides only duplicating the power consumption twice. Hence, power efficiency must go up to 25 times of the 2013 range [3]. This efficiency is derived from process technology, better hardware and software architecture and circuits, in addition to utilizing, parallelize and improving the thread from 10^7 to 10^{10} [3,4].

The matter that motivates researchers to leverage the heterogeneous PUs (multi CPU cores combined with any many-core accelerator such as GPUs or GFPA) collaboration to achieve high-performance computing. This way, we can benefit from the advantages of each and leverage the intelligent combination of both so as to achieve exascale performance and power consumption. Heterogeneous computing systems (HCS) are considered by many researchers the Exascale Computing system outrigger [3,4]. In an HCS, a various types of computing nodes, that are characterized by unrelated capabilities and equipped with spectrum types of computation units, are all interconnected via a highspeed network. The benefit of using different computing units (CU) types that each type of the heterogenous CU satisfies one type of application either memory or computing intensive application, see Fig. 2. The most efficient way to achieve the benefit of the spectrum types of the computing resources is best fit scheduling.

The efficient scheduling framework is capable of partitioning a job into small tasks, scheduling them on the HCS processing units in an efficiency way which achieves the minimum time-span and uses resources efficiently, in order for the job to be executed [3,4]. Mapping the tasks into the best-fit computing resources is the aim of task scheduling and allocating algorithms. As we note in [3,4], task scheduling is the mean critical aspect in managing these challenges. Also we found that the inappropriate scheduling of tasks on the computing resources offsets the profit of parallelization. Furthermore, inefficient scheduling algorithms compromise the benefit of efficient high-performance hardware devices.

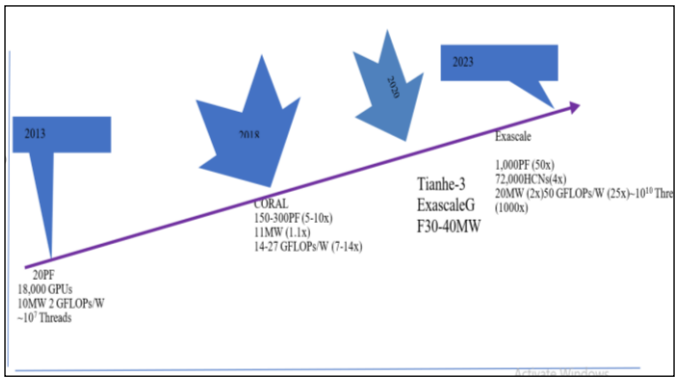

Fig. 1. The Road Map for Exascale.

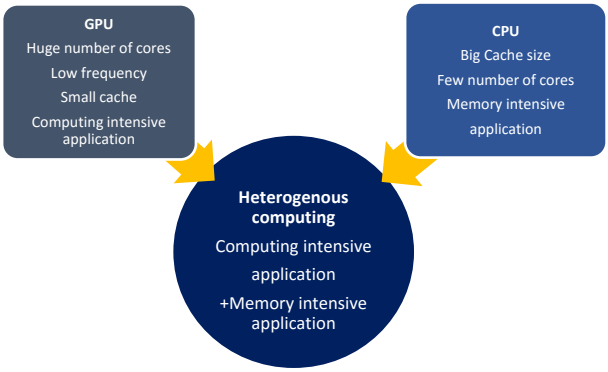

Fig. 2. Heterogenous Computing Advantages.

To solve the problems of scheduling and allocation, the scheduling algorithms aim to minimize the executing time of the application via properly allocating the tasks to the processors achieving the earliest finish execution time in a way that utilizes the parallelism of the resources efficiently. It also minimizes the overhead preprocessing computing of the scheduling algorithm itself. Therefore, in our previous work, we introduce the new hybrid scheduling algorithm dynamic variant heterogenous early finish time (DVR HEFT) [5,6].

In this paper, we continue our research and experiments on DVR HEFT algorithm by introducing and implementing the framework of Communication and Computation Aware task scheduler framework (CCATSF). The CCATSF framework consists of four parts, the first of which is the resource monitor, the second is the task scheduler, the third is the dispatcher and the fourth part is the resource manager. First, the resource monitor explores the resources in the system dynamically, collects the computing resources metadata, and updates the metadata in a continuous manner. The task-scheduler schedules the tasks based on an improved version of the Heterogeneous Earliest Finish Time (HEFT) heuristic, a directed acyclic graph (DAG) scheduling algorithm. The third part is the dispatcher. This module allocates the tasks to the available resources based on the output of the scheduler layer. Finally, the resource manager manages the scheduler system and the heterogenous computing resources. In this paper, we continue our research in improving the HEFT algorithm.

This paper contributes to the following aspects:

1) A Communication And Computation Aware task scheduler framework (CCATSF) software architecture is introduced.

2) The intersection of using DVR-HEFT: a new algorithm with the proposed framework for scheduling and allocating tasks on heterogenous resources is introduces. DVR-HEFT tackles the disadvantages of previous static algorithms by combining the improved HEFT algorithm using dynamic algorithm, the new algorithm considers optimizing the performance of heterogenous computing and the power consumption as well.

The next section illustrates the task scheduling problem formulation, followed by a background review of state-of-the-art algorithms. Following that, the proposed CCATSF framework and the proposed DVR HEFT algorithm are discussed. The random job generator implemented to generate the experiment's DAGs is also explained. Then our experiments are analyzed in detail, and the results received, using the Radom job generator is discussed.

II. Related Work

A. Task Scheduling Problem

We addressed the static scheduling for single application's tasks on Set P of processors in a heterogeneous system. The following is assumed:

1) There are P available processors to schedule the tasks of the job.

2) During the job execution, the processors are not shared.

3) No overhead at runtime as the system and job parameters are known at the compile time, which makes starting with static algorithm phase more desired.

The application tasks are usually represented using directed acyclic graph DAG, G = (V, E), where Set V is the nodes/tasks of the graph and Set E is the edges/communication cost of connected tasks. For all edges of Set E, there exists a weight. Example for DAG is illustrated in Fig. 3 and Table I. The edges weight represents the required precedence between the two tasks. The precedence is the predecessor's tasks that should be finished prior to the execution of the pointed task.

TABLE. I. Example DAG

Tasks	P1	P2	P3
T1	21	20	35
T2	21	17	17
T3	31	27	42
T4	6	10	4
T5	29	27	35
T6	26	17	24
T7	13	24	29
T8	29	23	36
T9	15	21	8
T10	13	16	33

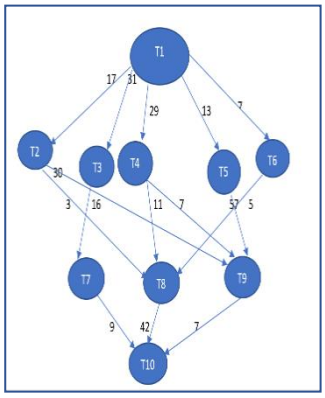

Fig. 3. Example for DAG Schedule.

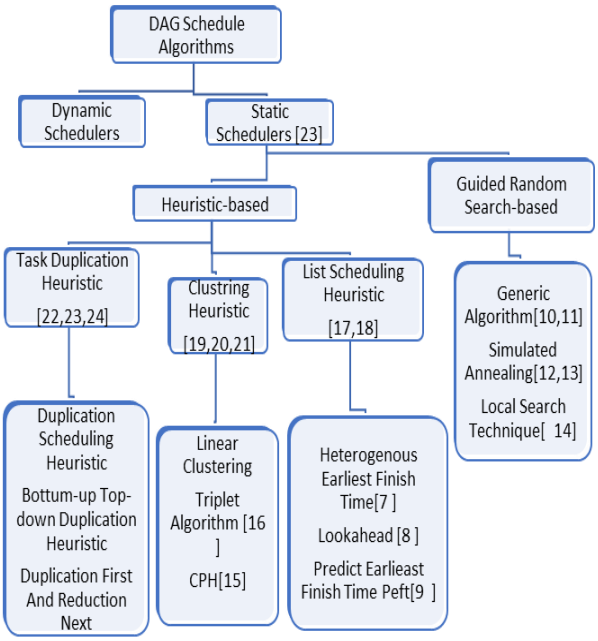

Fig. 4. Classification for DAG Task Scheduling.

There are two objectives the schedule algorithm has to achieve: 1) Employing the scheduler to order the tasks in a form which fulfills the precedence's requirements. 2) Fitting each task to the most appropriate and suitable processing unit available. First, we review the state-of-the-art algorithms which were our target in this study considering previous problems, then we introduce the proposed improvement algorithm.

B. State-of-the-Art Frameworks and Task Scheduling Algorithms

In Fig. 4 we classified the DAG scheduling algorithms. This figure illustrates that the scheduler algorithms are divided into two types: static [7-24] and dynamic. The static has two subtypes: heuristic based [7-9, 15-24] and guided random search based [10-14]. The figure also illustrates the different types of each of the latter two subtypes.

In our research we focused on heuristic based algorithms. The heuristic based are in turn divided into three types: task duplication [22,23,24], clustering [15,16,19,20,21] and list scheduling [7,8,9,17,18]. In our research we focus on the list scheduling [7,8,9]. There are many algorithms classified as list scheduling algorithm, the most cited types are:

- Heterogeneous Earliest Finish Time (HEFT) algorithm [7].
- Lookahead scheduling algorithm [8].
- Predict Earliest Finish Time (PEFT) [9].

Therefore, we based on them for the evaluation of our work.

Here we illustrate with more details the state-of-the-art list scheduling algorithm HEFT that we improved.

C. Heterogeneous Earliest Finish Time (HEFT) Algorithm

HEFT algorithm as well as PEFT and lookahead algorithm involves two stages [7]: 1) Prioritizing the tasks, and 2) Selecting the processor units. In the first stage of HEFT algorithm, the upward rank of tasks is computed for prioritizing the tasks. As HEFT algorithm is communication/computation aware algorithm, an upward rank of tasks is calculated using the corresponding communication and computation costs. For each task, the upward rank represents the biggest path from the starting task to the exit task. The output of the first step is a list of tasks organized in a decreasing order based on their upward rank values. In the second stage, the tasks are allocated to an appropriate processor which minimizes the early finish time for each task. Using an insertion-based policy, HEFT algorithm fits tasks in the earliest idle time slot between two scheduled tasks on a processing unit, HEFT time complexity is ($|V|2^p$) The proposed DVR HEFT algorithm improves the HEFT algorithm as it is communication and computation aware.

III. Proposed Communication and Computation Aware Task Scheduler Framework (CCATSF)

A Communication and Computation Aware task scheduler framework (CCATSF) is introduced in Fig. 5 and 6.

A. The Proposed CCATSF Framework Objectives

The objective of this work is the following:

1) We propose a task-scheduling technique for Exascale Computing that overcome the previous task scheduling frameworks weaknesses. The previous limitations are load balancing in a heterogenous environment, resources underutilization, fair resource mapping in the constrain of reduce communication and energy consuming. The proposed framework is based on reducing the communications and the computations time.

2) We aim to use the DVR HEFT algorithm to implement hybrid scheduling frame work to schedule and allocate tasks on CPUs-GPUs architectures.

B. The Proposed CCATSF Framework Architecture

A Communication and Computation Aware task scheduler framework (CCATSF) architecture layers are illustrated in Fig. 6. The CCATSF framework consists of four sections. Each of four sections consists of several sub modules. The first of which is the resource monitor, the second is the resource

manager, the third is the task scheduler and the fourth is the dispatcher or allocator. The resource monitor includes two modules: the monitor that explores the resources in the system dynamically, and the collector that collects the computing resources metadata and updates the metadata in a continuous manner. The resources manager included two subsections; the resource selector and the resource collaborator. The task-scheduler get the resources meta data and the tasks metadata, that are used to schedule the tasks based on an improved version of the Heterogeneous Earliest Finish Time (HEFT) heuristic, a directed acyclic graph (DAG) scheduling algorithm. HEFT algorithm, which is compatible efficiently for heterogeneous systems, improved without increasing the time complexity. The proposed DVR HEFT algorithm in run time utilizes the monitor module which will keep track with the cores status and save the processor's meta-data updated continuously. If any of the processers is idle, the new task will be mapped to the idle processor that satisfies the insertion policy constraints. If there is no idle processor, the task -via the dispatcher module- is inserted as the tail of one of the processor's queue which achieved the earliest execution time. When there is more than one processor choice, the algorithm computes for each processor pi, the actual early finish time of the task then it is inserted as tail of the pi ready queue of the processor which achieved earliest finish time would be chosen. Another feature is that it keeps turning the processors to the lowest energy consumption if they have no ready tasks in their queues, thus improving energy expenditure.

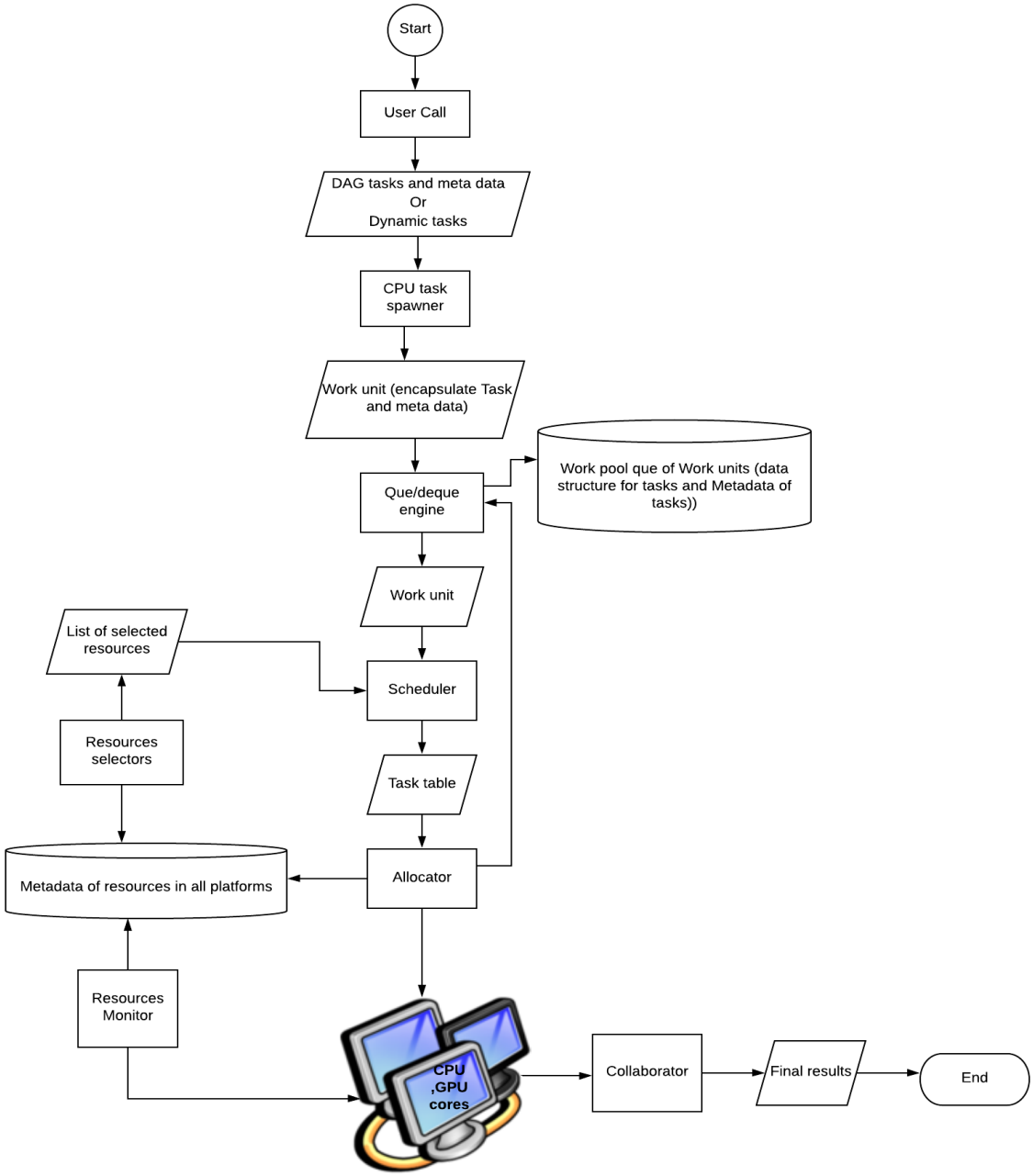

Fig. 5. CCATSF Framework Data-Flow Graph.

C. The Proposed CCATSF Framework Modules and Data Structure

Here are some more details regarding the modules and the data structured used in resources metadata as follows:

- Node (node-id, processor-type, operating-system, environment-id)
- CPU (processor-type, speed, no-of-cores, status, node-id)
- GPU (processor-type, speed, no-of-cores, status, node-id)
- Memory (type, size, status, node-id)

The proposed CCAFST framework contains several modules and submodules. Fig. 5 illustrates the dataflow between these modules and submodules in the framework. The system first receives the DAG tasks from the decompose layer which is out of the scope of this paper. The modules in the decompose layer convert the application into linked list represents a directed acyclic graph**.** Following the framework modules:

- CPU task spawner: Receives tasks from user and task meta data such as CPU code of the task and GPU code, successors, predecessors, communication time, and other related graph dependency task meta data. It receives tasks from the user as a directed acyclic graph (DAG) that determines the parallel and sequential tasks and related dependencies. In our case, the system user is the programmer. It initializes the task by creating an object-type work unit filling the work unit parameters such as task ID, task status, input size, output size, and memory size, CPU code, GPU code. The output of this module is the work unit which encapsulates the task and the meta data.
- Que/deque engine: Receives work unit from "CPU task spawner" and enqueues the work unit in the data structure queue. A task is deleted from queue once the execution of the task and its children finishes. It produces ready-task table, the CPU. The algorithm has a loop; if a new task arrives, it is included in the updated version of the task table.
- Scheduler: The scheduler receives the task ID as input, the related metadata and the available resources metadata. This module has many other sub modules used based on the algorithm DVR-HEFT. Then it does the mapping between the tasks and the resources by applying the DVR HEFT algorithm. DAG is a graph that defines the tasks and the dependences as nodes and communication cost as edges. The scheduler input is DAG and the output is the list of tasks and related resources-ID that are passed to allocator.
- Allocator: The allocator consists of a number of modules that allocate the tasks into resources based on scheduler output. It requests the queue engine to send the work units of the tasks that are listed in the task table. The allocator uses a system calling APIs of the target operating system. At the run time the allocator software modules cooperate with the scheduler software modules to apply the proposed dynamic algorithms work share and work steal. The algorithms would be implemented as dynamic library.
- Resources meta data collectors: These modules collect the meta data of the resources in the system number, type of processors, architecture memory size, speed of processor, and all other meta data required for specifications of processors. All the meta data are continuously updated collaborating with the assist of the resources monitor and stores in processor data structure. It includes many software modules for collecting the available resources meta data. There is a module for each platform that calls the API function of the target operating system for collecting meta data of the resources of the target machine to be stored in the metadata of resources. Each sub-module collects the metadata of available resources and sends them to a metadata manipulator module.
- Resources monitor: Collaborates with resources collectors as we mentioned before. In addition, the monitor keeps track of the resources' status. The resources' status is either idle, busy or fail.
- Resources selector: The resource selector determines the available resources (idle or low-load) and their status based on output of resources monitor.
- Resources collaborator: Collaborates between the executed resources to reduce the results that are passed later to the user.

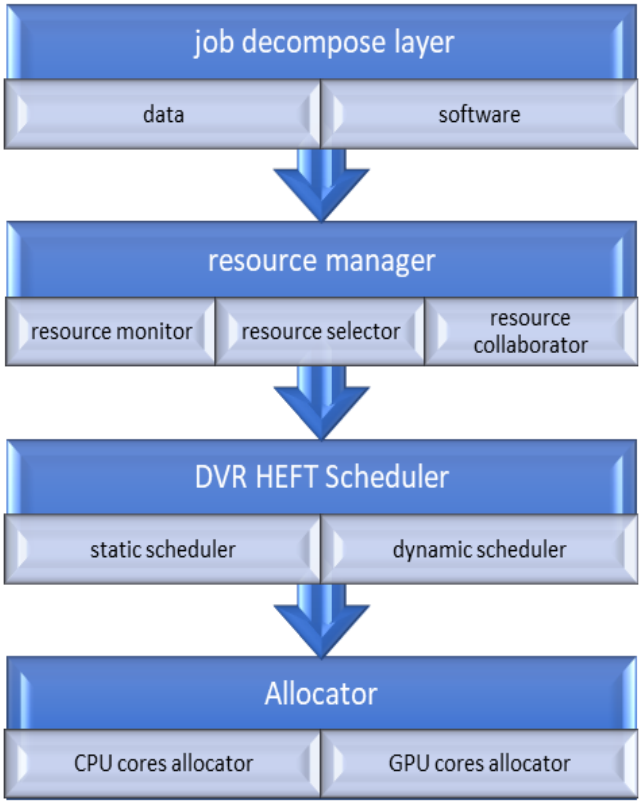

Fig. 6. CCATSF Framework Architecture Layers.

IV. Proposed DVR HEFT Algorithm

In this part, the algorithm that our proposed framework is based on is introduced. The algorithm consists of two parts: static and dynamic.

A. The Static Part

In the static part, the input is DAG. As all static algorithms, the first stage computes the priority of the tasks. When prioritizing tasks in HEFT algorithm, the upward ranking of tasks is considered. The upward rank, *ru(i)*, of a task *i* is defined recursively using the following equation:

$$\text{ranku}(i)=\{f(w_i)+\max_{\forall j\in Si}(avr(c_{i,j})+\text{rank}_u(j))\} \quad (1)$$

where w_i defined the *task's i* computation cost, S_i , the *task's i* immediate successors set. $C_{i,j}$ is the *task* $_I$ — *task* $_j$ communication cost. Assumption: when i and j allocated on the same machine, communication cost is zero.

The function $f(w_{ii})$ produces the task weight value. This value is dependent on the task's computation cost on each processor. In the HEFT algorithm, f(Wi) function is calculated using the average of the computation time on each machine.

$$f(Wi) = avr.(wp_1,wp_2,\ldots.wp_{n-1},wp_n) \quad (2)$$

Such that P={p1,p2,..pn} where P is the set of processors.

Nevertheless, in a heterogeneous environment, typically, the values in which the weights are based on cannot be considered as constant. This is related to the indeterministic behavior of the HPC environment resources. Similarly, the values that weigh the nodes also cannot be constant. Therefore, the computation cost of the task may vary, depending on the efficiency and the performance of the machine on which the task runs. Consequently, in the heterogeneous setting, there is a variety of different approaches to compute the node's weight, Thus, the scheme to compute the weight of a node Wi could be obtained as ad hock choice that may, in some cases, improve the execution time, but does not necessarily improve other cases [5,25]. Consequently, we obtained three schemes for computing the upward rank of the tasks.

1) We weigh the tasks based on the average of their corresponding execution time across all machines, similar to heft algorithm, Eq. (1).

$$f(Wi) = avr.(wp_1,wp_2,\ldots.wp_{n-1},wp_n) \quad (2)$$

2) It can also be obtained using the best case.

$$f(Wi) = \text{Min}(wp_1,wp_2,\ldots.wp_{n-1},wp_n) \quad (3)$$

3) weigh using the worst case.

$$f(Wi) = \text{Max}(wp_1,wp_2,\ldots.wp_{n-1},wp_n) \quad (4)$$

Each one of the schemas of equations (2), (3), (4) give a different order task list. As a result, when having multiple choices of rank function (and the values it returns), the quality of the schedule produced would improve [5,25]. Thus, we suggest that the performance of HEFT can be improved by considering the three variant upward rank in the stage of prioritizing the tasks [5,6]. Then we check the make span of the schedules produced by each scheme and take the shortest make span's schedule list and set it as the selected schedule. This may slightly increase the cost of the algorithm, but it is a trade-off worth making. In order to improve the execution time of the algorithm, we simultaneously calculated the variant upward rank of the tasks using the three schemes then apply the second HEFT stage of selecting the resource. We then choose the optimum schedule between them, i.e. the schedule that gives the earliest finish time for the exit task. By utilizing the parallel computing for this preprocessor calculation, the algorithm time complexity will not be compromised.

Algorithm1: pseudocode DVR-HEFT algorithm

```
1.  1.DVR HEFT Algorithm
2.  Define wi,EFT,taskID,ranku,P,t
3.  Input int ranku,wi,EFT,PID,taskID
4.  Output mapping PID,taskID
5.  Begin algorithm
6.  #the static part of the algorithm
7.  for each task compute tasks ranku
8.  f(wi)=Min(w^p1..w^pn )
9.  rank tasks using the ranku as list1
10. for each task compute tasks ranku f(wi)=Max(w^p1:w^pn)
    rank tasks using the ranku as list2
11. for each task compute tasks ranku f(wi)= avr.(w^p1:w^pn )
    rank tasks using the ranku as list 3
12. End Do parallel
13. For all generated rank tasks list: list1, list2, list3 do
14. while there are unscheduled tasks do
15. t ← unscheduled task with highest ranku
16. For each pi∈P //P set of the processors
17. schedule t on Pi using HEFT
18. End For ,
19. End while
20. compute EFT of exit task// this step generate EFT 1 for
    //list1,EFT2for list2,EFT3 for list3 .
21. selected scheduler ← find min(EFT1,EFT2,EFT3)
22. end for
23. Turn to low energy consume mode
24. End for
25. End algorithm
```

B. The Dynamic Part

The second part of the algorithm is the dynamic part. In some cases, tasks are submitted at the run time as in real time systems and irregular workload. In practice, however, the properties of computing nodes can change dynamically, especially in situations where the worker nodes are shared with other system users [26].

In this case, dynamic algorithm is required. In comparison with static scheduling, dynamic task scheduling makes decisions regarding task assignments at run time, allowing computation to adapt to changes in the computing environment, such as the processing power on a particular node being preempted by other system users, as the scale of the application under scheduling which hugely increased the need for robust dynamic algorithm is not a trivial matter. In [26], the researchers pointed out that static algorithm do not always negatively affect performance. In fact, static features may

improve dynamic algorithms while dynamic features may optimize static algorithms. Therefore, we combine VR-HEFT algorithm with features that enable the scheduler to receive tasks at run time and schedule them efficiently.

At the run time, each processor has a tasks list. When the task dependency is satisfied, the task is queued in a processor's queue named "ready tasks queue" to be later dispatched onto the cores. The tasks are inserted using the insertion police used in HEFT algorithm [7]. If a new task is received at the run time, how does the algorithm schedule it? This point is explained with more details when we discuss the framework software architecture and modules. The algorithm in run time as we mentioned before, keeps track with the cores status and saves the processor's meta-data updated continuously. If any of the processers is idle, the new task will be mapped to the idle processor that satisfies the insertion policy constraints. If there is no idle processor, the task is inserted as the tail of one of the processor's queue which achieved the earliest execution time. When there is more than one processor choice, the algorithm computes for each processor pi the actual early finish time of the task then it is inserted as tail of the pi ready queue of the processor which achieved earliest finish time would be chosen. Another feature is turning the processors that are idle, to the lowest energy consuming mode. When there is new task that needs to be allocated to that node, the resources monitor return it back to active mode which optimizes energy efficiency.

V. Experiment and Results

We conduct several experiments to evaluate the proposed Framework based on the proposed algorithm DRV HEFT algorithm. Also, we compare DVR HEFT algorithm against the state-of-the-art list algorithms, HEFT-in the traditional form-, Lookahead and PEFT in three sets of experiments using three metrics [7] makespan, scheduling length ratio (SLR) and efficiency. We first present the comparison metrics used for the performance evaluation.

A. Comparison Metrics

The comparison metrics are make-span, scheduling length ratio (SLR) and efficiency.

1) Make-span: First comparison metrics is the makespan which means the total time for the scheduling algorithm. It can be computed by finding the max actual finish time for the exit task in the application

Make-span = max (AFT(t_{exit}))

2) Scheduling length ratio: In addition to make-span we used the scheduling length ratio (SLR) which is better to compare DAGs with very different topologies.

SLR is defined as follows [7]:

$$SLR = \frac{makespan}{\sum_{n_i \in CP_{MIN}} \min_{P_j \in P}(w_{(i,j)})}$$

In *SLR*, the denominator is the minimum computation cost of the critical path tasks (CP_{MIN}), where there is no make span less than (CP_{MIN}). Thus, the best algorithm is the algorithm with the lowest SLR.

3) Efficiency: In the broad case, we calculate efficiency by dividing the speedup over the number of processors used in each run, where the Speedup is the ratio of the sequential execution time to the parallel execution time (i.e., the make span). By assigning all tasks to a single processor the computation time of all the tasks is minimized.

$$Efficiency = \frac{speed\ up}{Number\ of\ processors\ used}$$

The sequential execution time is obtained using the following equation [7].

$$speedup = \frac{sequential\ execution\ time}{parallel\ execution\ time}$$

(i.e., the speed up= the make span of schedule).toolbar.

B. Experiment Setup and Random Graph Generator

This is on progress research. Therefore, we conduct the experiment on the DAG task scheduling algorithm VR-HEFT, using a simulator. We implemented a random DAG generator that generates graphs characterized as follows:

- Single entry and exit nodes.
- Graphs have multiple levels that are created gradually. Each level randomly contains a range from 2 to half the remaining nodes.

The following parameters define the DAG shape:

n: the number of tasks in the DAG.

fat: Fat determines the width and height of the DAG. By the width of the DAG, we choose the number of the concurrent executed tasks, whereas by the height, we decide the DAG's number of levels density Density defines the number of edges between each two levels: high values indicate a high number of connections in time and low values mean a lower number of edges.

Consistency: Consistency determines the regularity of the number of nodes in each level: high values indicate similar number and low values mean dissimilar numbers.

Tasks Size range: Task's Size range determines the range in between the task's size.

In our study, we created a wide variety of DAG structures, assigning several values to some parameters in the DAG generator to compute the communication and communication cost. Here, we list these parameters that are used, and the values used

CCR (Communication to Computation Ratio): ratio between two summations the edge's weights and nodes' weights in a DAG;

β (range of computation cost percentage on processors).

The heterogeneity factor for processor speeds. A lower of β value shows that the computation costs for a task is almost equivalent among processors, whereas a higher value means different computation costs between processors.

In the experiments, we used the following parameters to generate random graphs:

n = [10, 20, 30, 40, 50, 60, 70, 80, 90, 100,200,300,400,500]

fat = [0.1, 0.4, 0.8]

CCR = [0.5, 1, 10]

β = [0.1, 0.5, 1]

Processors = [4, 8, 16, 32]

Task size range = [40-100, 350-500]

The previous parameters produced different graphs based on their various combinations. The four algorithms Lookahead, PEFT, traditional HEFT, and DVR-HEFT the improved version of HEF were implemented. Next, we present the experiments that we conducted and their results.

C. Experiments for the Comparative Study

1) Experiment 1: In the experiment 1, we measured the makespan of each generated graph using the four algorithms, then we got the average makespan as a function of the number of nodes in the DAG. Then we computed the SLR for the four algorithms. Fig. 7 and 8 shows the average of SLR.

We found that the proposed DVR-HEFT algorithm is better than HEFT by an average of 13 percent continuously until the number of tasks was 60 then it increased to 15 percent and again decreased to less than 7 percent until the number of tasks was 500 where it reached 5 percent. In contrast to Lookahead (another algorithm that improved HEFT) we found that lookahead is better than DVR-HEFT until 40 nodes then they are both are equal and after 80 nodes DVR-HEFT has even better performance. The worst performance of Lookahead is at 500 nodes

2) Experiment 2: The goal of the second experiment is to find the SLR as a function of CCR Fig. 9, we found that the performance improvement increased when the communication is increased specially when the CCR ratio is more than 1; as the DVR HEFT algorithm is communication aware. We also found that DVR HEFT is similar to both PEFT and HEFT, while they are better than Lookahead if the communication is little (0.5). The DVR HEFT performance is improved by 3 percent compared to the HEFT algorithm when the communication to computation ratio (CCR) is more than 0.5. However, when the CCR is 10, DVR HEFT, PEFT and Lookahead all similarly improve the performance HEFT in an equal degree in average.

3) Experiment 3: In Experiment 3 we computed the efficiency when we use different number of processors. Fig. 10 and 11 illustrate the results of this experiment. We found that DVR-HEFT improve the efficiency as a function of the number of the processors similar to Lookahead algorithm and superior to PEFT and HEFT that is less in efficiency than DVR-HEFT. The efficiency of the algorithm is based on the performance and the number of processors utilized in the computation. If we improve the efficiency and the load balanced, the performance will not necessary improve. Lookahead improves the load balance more than PEFT, therefore it improves efficiency even though the performance of PEFT is better. DVR HEFT improves both efficiency and performance at the same time. Next, we discuss the results.

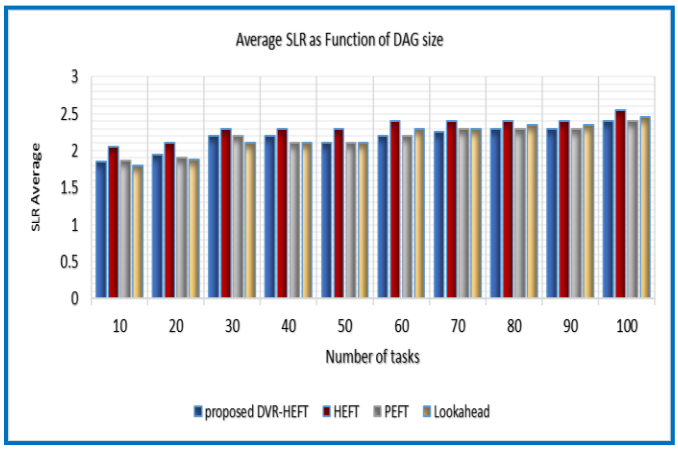

Fig. 7. Average SLR as Function of DAG Size.

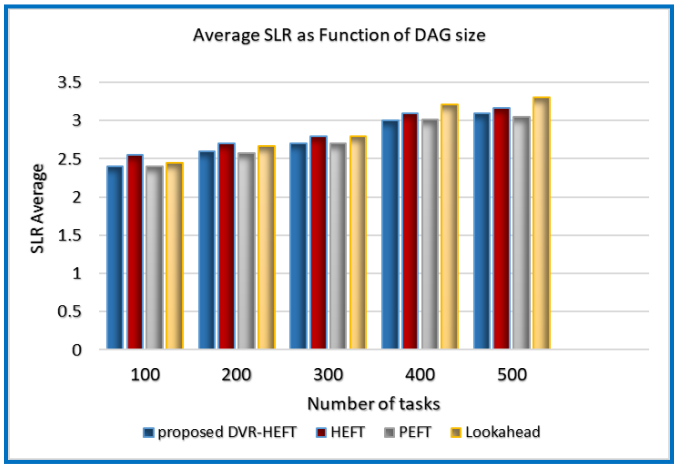

Fig. 8. Average SLR as Function of DAG Size.

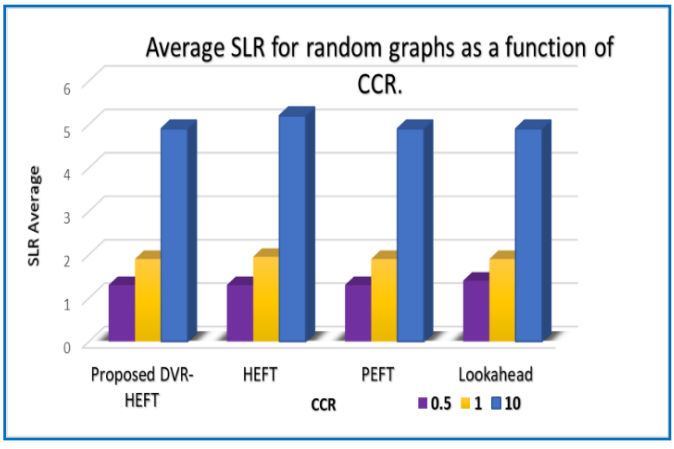

Fig. 9. Average of SLR as a Function of CCR.

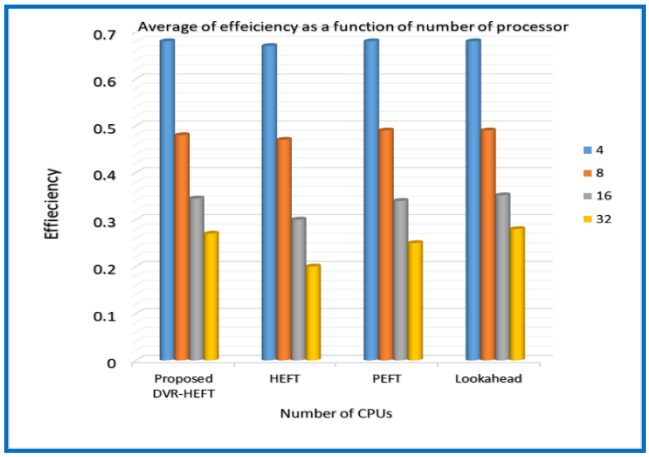

Fig. 10. Average of Efficiency as a Function of Number of Processor.

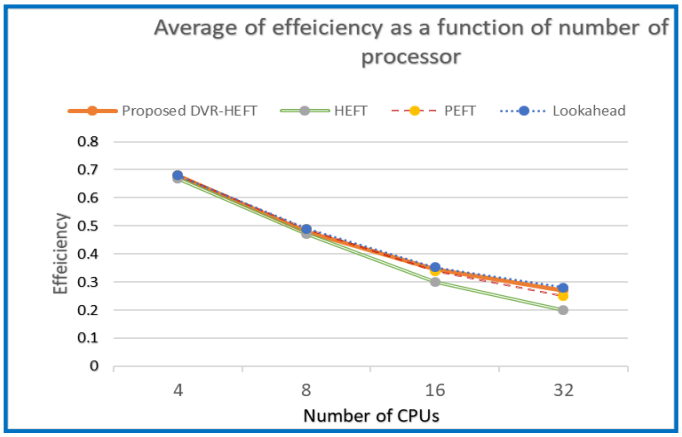

Fig. 11. Average of Efficiency as a Function of Number of Processors.

4) Discussion results: Several experiments have been conducted to evaluate the DVR-HEFT algorithm; the proposed bio-objective hybrid scheduling algorithm that the proposed CCATSF framework is based upon. CCATSF framework is a hybrid task scheduling framework. The experiments show that DVR-HEFT improves HEFT algorithm better than the previous HEFT improving algorithms with lowest quadratic time complexity. Exascale Computing environment requires task scheduling for thousands of tasks, hence, we propose DVR HEFT as a hybrid algorithm to prioritize tasks and schedule them by mapping them to available resources based on the earliest finish time. It also schedules tasks at runtime to idle cores, and in case there is no ready tasks, it turns the processors status to the lowest energy consumption. Beside the scheduling module, our proposed CCATSF framework involves other modules for allocating tasks on the processor unit resources. As future work, we will implement several algorithms for allocating that suitable for Exascale computing.

As this research is still on progress, we evaluated our algorithm based on the random job generator. We generated jobs or graphs that involve a huge number of tasks such as 500 tasks and more. Such type of jobs is suitable for achieving the number of tasks that are comparable to Exascale computing scalability. We conducted these experiments that emphasized the important effect of the task size and number in the application under execution on the performance of the algorithm. It also stresses on the effect of the communication that our proposed algorithm was able to overcome. As future work we will evaluate CCATSF based on the real applications to justify the reliability of both the DVR HEFT algorithm and the CCATSF framework.

VI. Conclusion and Future Work

In this paper, we introduce the task scheduler CCATSF framework. The framework is implemented based on a new hybrid DAG scheduling algorithm; Dynamic Variant Rank HEFT (DVR-HEFT) algorithm. The aim of this in-progress research is to propose a task scheduler framework that is applicable to manage the Exascale computing complexity in terms of scalability and heterogeneity. We first improve HEFT, one of most cited state-of-the-art scheduling algorithms by introducing the hybrid DVR-HEFT algorithm. Then we proposed the task scheduler framework CCATSF based on the proposed DVR HEFT algorithm. Our optimization is based on decreasing the communication and computation time. Consequently, we are able to decrease the energy consumption. The framework is also able to decrease the energy consumption by improving the utilization of resources. Several experiments have been conducted based on a random job generator to evaluate the CCATSF framework and compare the DVR HEFT algorithm to HEFT and some of the state-of-the-art static DAG scheduling algorithms. The results show that DVR-HEFT improves HEFT algorithm and is superior to Lookahead algorithm especially when the number of tasks is more than 100, which Exascale systems requires. Performance using DVR HEFT algorithm increased by an average of 13 % continuously until the number of tasks was 60 then it increased to 15 percent and again decreased to less than 7 percent until the number of tasks was 500 where it reached 5 percent. We concluded that DVR-HEFT improves HEFT algorithm better than the previous HEFT improving algorithms with lowest quadratic time complexity. If we consider scheduling tasks for Exascale Computing environment, thousands of tasks are expected. For that reason, our next step in our in-progress research is to evaluate the task-allocating module algorithms of the CCATSF framework using real applications on more scalable and heterogenous resources.

Acknowledgments

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A Mobile-based Tremor Detector Application for Patients with Parkinson's Disease

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***Abstract*—Parkinson's disease affects millions of people worldwide and its frequency is steadily increasing. No cure is currently available for Parkinson's disease patients, and most medications only treat the symptoms. This treatment depends on the quantification of Parkinson's symptoms, such as hand tremors. The most commonly used method to measure human tremors is a severity scale, which lacks accuracy because it is based on the subjectivity of neurologist review. Furthermore, the use of severity scales prevents the extraction of information from tremor activity, such as speed, amplitude, and frequency. Therefore, a mobile application was developed to measure the hand tremor level of Parkinson's patients using a mobile phone-based accelerometer. Agile method was used to develop this application, and Android Studio and Android Software Development Kit were utilized. The application runs on an Android smartphone. This application allows patients to identify their tremor activity and subsequently seek relevant medical advice. In addition, a neurologist can monitor tremor activity of patients by analyzing the records generated from this application.**

Keywords*—Agile; mhealth; mobile application; Parkinson; tremor detector

I. Introduction

The increasing number of patients with Parkinson's disease has resulted in the prevalence of many symptoms, such as tremors, stiffness, bradykinesia (slowness of movement), foot cramps, and postural alteration [1]. Procedures for monitoring tremor of patients are quite challenging because they require patients to undergo tests, and neurologists must obtain a detailed history of patient's symptoms prior to their analysis [2]. However, the clinical observation of experts is time-consuming and may not necessarily be accurate because the test environment may impose pressure on the patient. Insufficient methods to identify and assess tremors over a long duration require patients to manually complete their tremor evolution for days. Owing to the unavailability of tools to accurately detect tremors, determining whether the stage and cause of patient's tremor are worsening or are side effects from medication intake is impossible.

In response to the aforementioned problems, several quantitative methods were developed by previous researchers. These methods include electromagnetic detector device [3], mechanical linkage devices for fingertips [4], electromyography [5], wearable sensors [6], miniature gyroscopes [7], digitizer tablets [8], tremor pens [9], and accelerators [10]. However, in addition to their high cost, the usage of these devices is challenging because they require technical expertise to manipulate the hardware and analyze the results [2].

Therefore, a mobile application for detecting tremors for patients with Parkinson's disease was developed at an affordable cost and can be downloaded onto a user's smartphone. Patients can also continuously monitor their health state.

II. Theoretical Background

A. Measuring Parkinson Tremor

Experts on Parkinson's disease do not have sufficient resources to monitor symptoms, such as tremors, in patients of Parkinson's disease [11]. In most cases, inconsistent clinical visits resulted in insufficient and inaccurate information on patient health state for neurologists to plan for the most effective treatment. Some methods can be used to test human tremor [12]; the most commonly used method is the severity scale. This method requires a patient to draw multiple patterns, such as spirals, circles, and alphabets (Fig. 1).

The drawing is classified by neurologists based on a numerical scale, normally from 0 (no visible tremors) to 5 (strong disabling tremors). The drawings of patients are later compared with drawings and their classification from previous clinical cases. Thus, this method depends on visual comparison and expert subjectivity. Moreover, other important tremor attributes, such as frequency, amplitude, and speed, cannot be captured from this classification.

Therefore, clinical evaluation cannot provide the most accurate answer on the disease evolution because the abnormalities of individual patients are disregarded and the dependency on expert subjectivity is considered in the evaluation and classification of each patient.

B. Previous Applications

Several related systems were critically analyzed, and their strengths and limitations were used as a guideline to develop the tremor detector app for Parkinson's disease patients. Table I illustrates the comparison of system features and functions between previous systems and the proposed app in relation to Parkinson's disease patients. All system interfaces are simple and neat, except for the smartphone app, which was found to be confusing for first-time users. Most systems are also complex. The smartphone app displayed all data on the same screen, resulting in a crowded page display. Lift Pulse is

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confusing, and this situation is compounded by the absence of a user manual. A user must examine the app function while tremor data are not clearly displayed. Sensors and smartwatch apps require challenging hardware for users because the sensor must be accurately positioned, and this alignment is time-consuming. By contrast, ParkNosis and the proposed app are easy to use and equipped with a user manual for reference purposes.

Some functions were also compared among the six systems. The common function across all systems is the tremor test. Most systems display detailed results for tremor activity, such as amplitude, frequency, and acceleration. By contrast, Lift Pulse and ParkNosis do not display detailed results. In terms of the graph display, only the smartphone app for tremor detector does not have this feature. Three functions, namely, calculating tremor values, providing recommendations for tremor activity, and generating tremor activity report of users (including patient details and tremor activity record), were added to the proposed app.

In terms of record submission, the smartwatch app and ParkNosis use the database while the smartphone app sends data by email. The proposed app enables users to send their reports to family members and store them in the app's database. Lift Pulse and the sensor app do not provide this function. The smartphone app and Lift Pulse do not provide a user manual, causing difficulty to some users in understanding their systems.

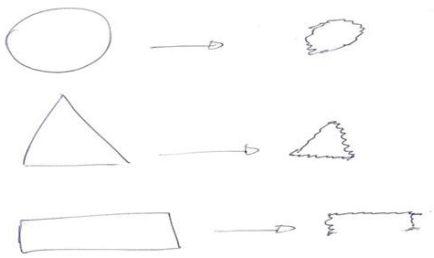

Fig. 1. Example of Patterns Drawn by a Patient with Parkinson's Disease [12].

TABLE. I. COMPARISON BETWEEN PREVIOUS SYSTEMS AND DEVELOPED APP

Features/ Functions	**Previous systems**					**Developed app**
	Smartphone app for tremor detector [13]	***Lift Pulse [14]***	***Sensor-based evaluator for tremor activity [15]***	***Quantifier for tremor activity using smart watch [16]***	***ParkNosis [17]***	***Tremor detector app***
User interface	Confusing for first-time user	Simple and neat	No user interface because this is a hardware	Simple	Simple and neat	Simple and neat
Complexity	Complicated – all data for tremor, accelerator, and user are displayed on the same interface	Confusing – no user manual, and tremor data are not clearly displayed	Complicated hardware use; sensor must be accurately positioned and set up is time consuming	Easy to use smartphone app but complicated hardware use	Easy to use; user manual is provided	Easy to use; user manual is provided
Tremor test	Main function	Main function	Main function	Main function	Sub function	Main function
Display of detailed results for tremor activity (amplitude, frequency, and acceleration values)?	Yes	No	Yes	Yes	normal and abnormal values only	Yes
Results display form	No visual display	Graph	Graph	Graph	Graph	Graph
Generate report for tremor activity?	No	No	No	No	No	Yes
User manual?	No	No	No	Yes	Yes	Yes

III. Method

The application was developed using the Agile method due to its iterative, incremental approach to enable early system. Delivery and real-time communication and teamwork [18], ensuring the fulfillment of user requirement. Joint application development (JAD) was also used to encourage user involvement through system design and development workshops [19], yielding to short development duration. The app development involved a number of phases. In the first phase, a JAD workshop was conducted between a subject matter expert with the app developer (author PXY) to determine app requirements, design, and analysis. In the second phase, user evaluation, including app scope and development risk, was conducted. The third phase involved app development based on user requirements, followed by app demonstration involving testing (user and user acceptance) and verification. These processes were iterated when users were not satisfied with the app. Appropriate and logical algorithms were used in developing the app.

A. Architecture

The tremor detector app for Parkinson's disease patients was developed in a two-tier client-server architecture. A database server is used to store data via the Internet while the mobile app performs the core functions and displays the related data.

B. Coding

The app modules were developed in phases using Java and Android Studio framework. The coding was completed in five months. Each function was tested to ensure its expected function and the absence of errors.

C. Testing

The app was tested based on functional and non-functional aspects. Black box testing was also conducted by utilizing a use case test technique. Moreover, an overall system testing was conducted to ensure that the app fulfills user requirements and is free from critical problems. Therefore, unit and user acceptance testing were respectively performed at the system and acceptance testing level. The test levels are appropriate for black box testing. In addition, the app used analytical and design testing techniques based on a requirement specification document.

User acceptance testing was conducted with three individuals: SME, an information technology student, and a science student. The SME confirmed that the app was appropriately developed based on user requirements. The two other subjects verified the functionality of all app functions. The black box testing involved a testing plan, testing procedure, and test log. All testing statuses for the app indicated "pass".

IV. Tremor Detector App for Patients with Parkinson's

The app used an accelerometer, a detector for testing patient tremor. The accelerator has been tested, evaluated, and proven to be potentially beneficial in treating Parkinson's disease [10].

Furthermore, neurologists can obtain readings on frequency, amplitude, and speed from the tremor activity of a patient generated from this app. They no longer need to use the severity scale, which is time-consuming and inefficient, because they do not need to ask patients to draw multiple patterns that require additional time for analysis and compare them with previous cases. Instead, neurologists can obtain patient readings and monitor tremor levels by simply using this app.

A. User Type

The app was designed for three types of user: Parkinson's disease patients, neurologists, and regular users. The modules for Parkinson's disease patients are account registration, tremor test, report submission, and test record history. Functions for regular users are limited to tremor test only, while the neurologist user module includes account registration and patient tremor activity record for analysis. Fig. 2 and 3 show the flowcharts of modules

B. Interface Design

1) Registration: In order to register for the app, users must fill in detailed information and verify them via their email account for security (Fig. 4).

2) Tremor test: Users can start the test by pressing the "start" button, and they must hold their mobile phone for one minute to obtain the test results, as shown in Fig. 5. For existing registered users, a report containing patient information and tremor activity results would be generated. Reports would not be generated for guest users. Fig. 6 illustrates interfaces for starting tremor activity testing, and Fig. 7 shows tremor activity results of a user. Fig. 6 presents a report generated based on registered user information and their tremor activity results.

3) Report submission: After taking the tremor activity test, registered users can submit their reports to their family members via email by pressing the "submit report" button (Fig. 8).

The tremor detector app for Parkinson's disease patients is beneficial for monitoring tremor evolution. Patients can use the app to discover their health state while neurologists monitor their patient condition by examining their record. The app functions were tested to ensure accurate functionality and the absence of errors. The app has numerous benefits and limitations.

The app is accessible, user-friendly, and features essential Parkinson's disease diagnoses. Owing to its mobility, the app can be assessed anytime and anywhere. The interface of the app considered aesthetic aspects by using and coordinating appropriate colors, graphics, and element positions. The app functions are easy to use and learn. The app also stores patient information and generates reports and graphs for reference and monitoring.

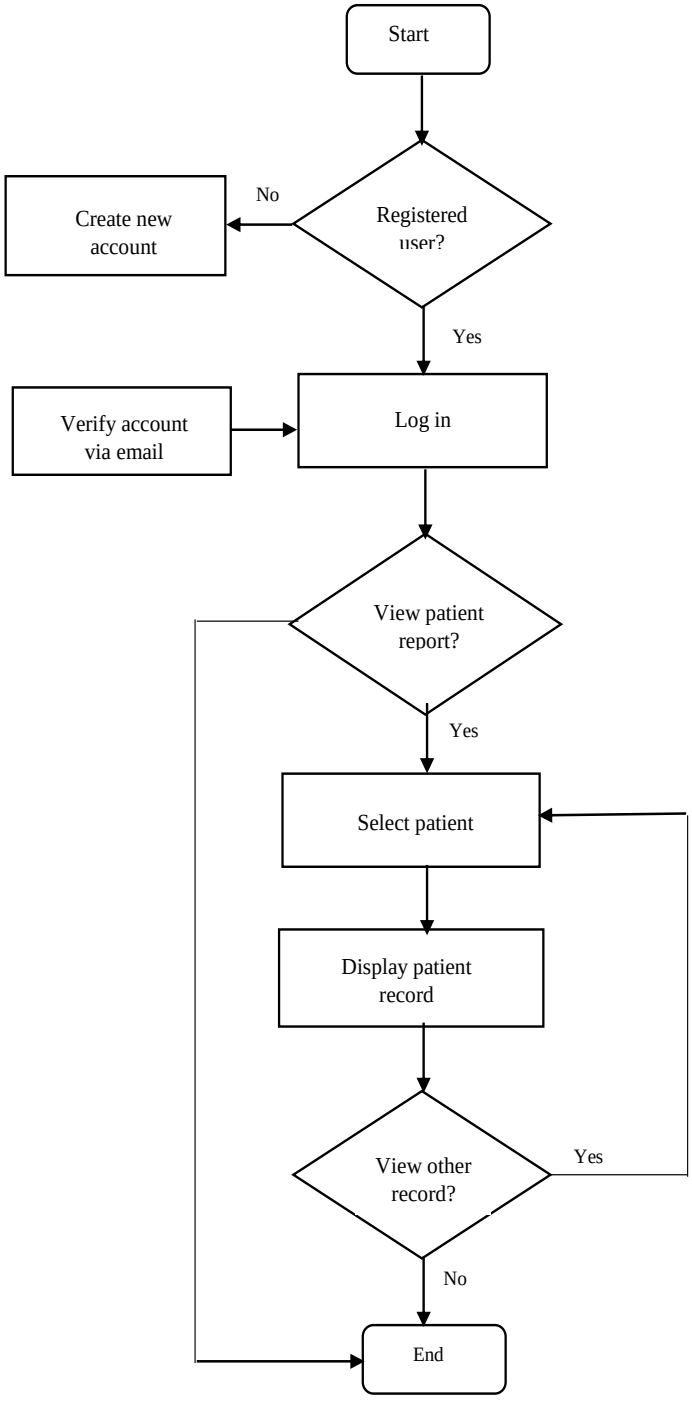

Fig. 2. Flowchart for Parkinson's Disease Patient.

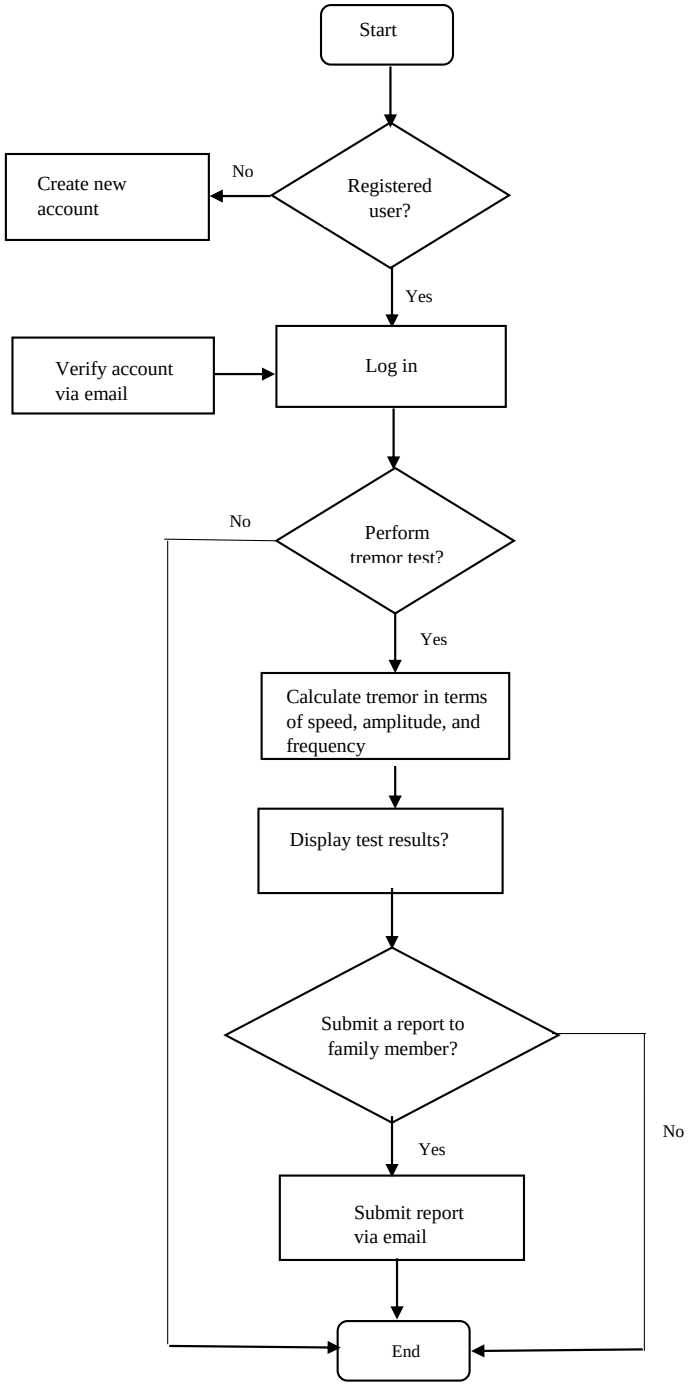

Fig. 3. Flowchart for Parkinson's Disease Neurologist.

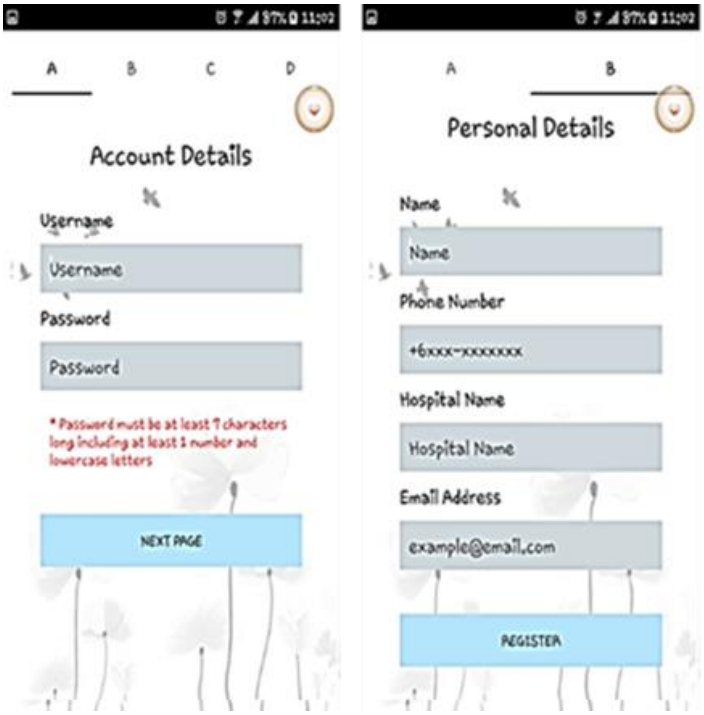

Fig. 4. Account Registration Interface for Parkinson's Disease Patient.

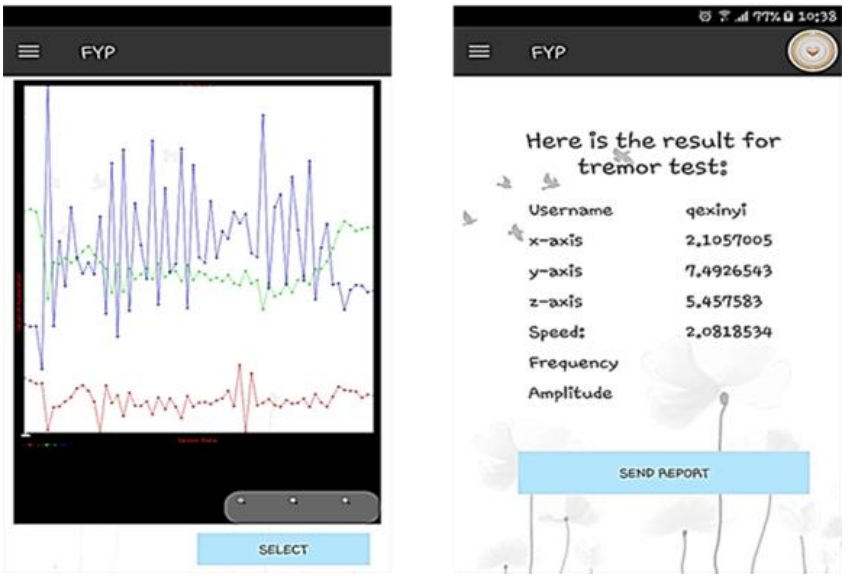

Fig. 5. Interface for Performing a Tremor Activity Test.

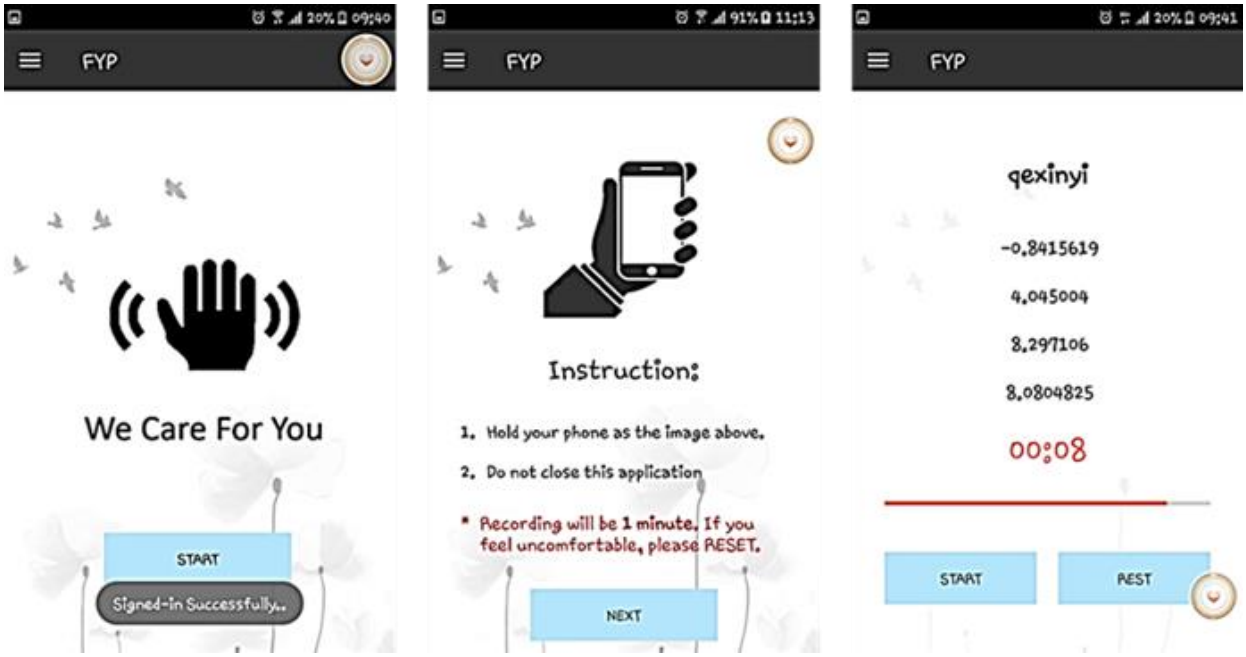

Fig. 6. Tremor Activity Results of users.

Fig. 7. Report Generated based on Information of a Registered user and her Tremor Activity Results.

Fig. 8. Interface for Submitting Tremor Activity Report for Parkinson's Disease Patient.

V. Conclusion

Overall, the tremor detector app for Parkinson's disease patients has successfully achieved its intended objectives. The app may be potentially beneficial to Parkinson's disease patients and neurologists in effectively managing the disease. Instead of manual, subjective analysis of patient drawings, the app enables neurologists to conveniently analyze patient tremor records in graph form. Tremor frequency, amplitude, and x, y, and z axes can be recorded in a report generated by the app during patient tremor test. Moreover, patients can monitor their health state and subsequently seek further medical assistance by comparing their current and previous record history.

However, the app has a number of limitations including restricted platform, communication language, and comparison ability. The app can only be run on Android-based mobile phones. Although patients can generate their tremor test results and respective graphs, they are unable to compare the latest test results with the previous ones on the same graph. This condition may cause difficulty for patients because they have to view their records in a separate graph. In addition, the app does not provide a function to directly translate its interface into another language by a "change language" function. The app language is assigned based on the smartphone installed language, and it only supports three languages, namely, Malay, English, and Chinese.

The app can be improved in the following ways: i) using other platforms apart from Android, such as IOS or Window operating systems; ii) enabling users to compare multiple data, such as those from x, y, and z axes with previous records on the same graph, to evaluate their health state and further discuss their situations with neurologists; and iii) utilizing multiple communication languages through a translation function to support the language preference of users.

Acknowledgments

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The Effect of Social Feature Quality on the Social Commerce System

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***Abstract*--The emergence of social networks has triggered the evolution of e-commerce to what is now known as social-commerce (s-commerce). However, s-commerce users experience problems related to its social features that affect s-commerce effectiveness. Therefore, the paper examines the effect of social feature quality (SFQ) determinants on s-commerce from customer perspective by adapting the information systems success model. A total of 220 online survey responses were analyzed by using confirmatory factor analysis and the structural equitation model to test the proposed model. SFQ shows a significant effect on perceived usefulness and customer satisfaction with an s-commerce system, whereas relationship support quality shows a significant effect on perceived usefulness and customer satisfaction with an s-commerce system but not on social support. A significant relationship is also identified among perceived usefulness, customer satisfaction, and net benefits of an s-commerce system.**

Keywords—Social feature quality; relationship support; social support; s-commerce; e-commerce; customer satisfaction

I. Introduction

The increasing interest in Web 2.0 and social media has triggered the evolution of conventional electronic commerce (e-commerce) to social commerce (s-commerce). S-commerce has various definitions, with its essence lying in social media, community, and commerce activities [1]. Therefore, s-commerce can be defined as a form of an online business that combines e-commerce with "community" to facilitate the consumers' online commerce activities (i.e., selling and buying) [2]. In this context, the community is supported by their use of social media or Internet-based applications, including social networking sites (SNS), blogs, and videos (YouTube), that are designed to attract users (i.e., customers). Therefore, in the s-commerce context, Internet-based applications are used to accomplish commerce-related activities, including buying, selling, distributing information about products and services, and sharing online shopping experiences [3].

Soon after its emergence, SNS has attracted usage as an s-commerce platform where customers can engage in online shopping [3]. Previous studies show that using SNS as a business platform greatly contributes to s-commerce revenue. For example, Wong [4] reported that 40% of Malaysian Internet users use SNS for online shopping and 51% of them admitted that they started shopping online after their exposure to SNS (i.e., Facebook). These figures indicate that SNS is a well-accepted online shopping platform that can persuade people to purchase products. Despite the potential benefits of SNS such as saving time and money, customers are often exposed to problems related to the social features of s-commerce, including direct and indirect communication, user-generated content (UGC), and interaction in online communities, thereby influencing the reputation of SNS-based commerce and the customer satisfaction [5-8]. Customer satisfaction can influence the level of system use and vice versa as well as encourage users to increase their system use. Meanwhile, an effective system use can lead to customer satisfaction depending on the ability of users in maximizing their utilization of the available features and functions in the system [9]. These effects, in turn, may lead to customer loyalty and repurchase behavior, which will enable sellers to establish and maintain their relationships with their customers while gaining profit. Therefore, the social feature quality (SFQ) determinants that affect customer satisfaction must be understood from the customers' perspective. Given that s-commerce is still developing as a new sales platform, some studies have already begun to examine this field, particularly its social features. We adapt the information systems (IS) success model [10] to examine the effects of these social features on the customer satisfaction with s-commerce from the customers' perspective.

This paper is organized as follows. Section II presents the theoretical background of the study, the model utilized in the previous literature to investigate the customer satisfaction with s-commerce research model, and hypotheses. Section III explains the research methodology and Section IV reports the findings and offers the discussion. Section V provides the conclusion.

II. Related Works

A. S-Commerce and SFQ

An s-commerce community is supported by social media where customers go beyond seller information and directly or indirectly interact with other customers when making their final purchase decisions. In this case, social interaction plays an important role in s-commerce platforms and produces different value for businesses [6,11]. Apart from social interaction, UGC implies that users or consumers can create and publish their own content to help other users make purchase decisions in an online marketplace [12]. Therefore, social features play important roles in s-commerce. These

features promote "socializing" behavior or community interactions that can influence the online shopping decisions of other members (i.e., customers) [6,11]. Socializing is an essential foundation of s-commerce [5]. SFQ is mainly measured based on social support and relationship support [5,6,11], both of which have significant effects on the behavior of users toward s-commerce, which in turn can increase the perceived usefulness and customer satisfaction with SNS-based commerce.

Social support explains social supportive communication in an online context (i.e., SNS). The emergence of SNS functions has allowed community members to go online shopping while simultaneously socializing with other members or seeking help from other SNS functions (e.g., ratings and recommendations) when making purchase decisions [6,13]. SNS also provides community members with an important source of social support through commercial information sharing, which provides these members a sense of belonging and appreciation, thereby motivating them to participate in s-commerce discussion. Consequently, the relationships among the community members are enhanced, thereby increasing their confidence to shop online via SNS-based commerce [5].

The participation of customers in the community [14] can increase their commitment, promote long-term relationships [5,6,11], and build their loyalty to the online community and the SNS-based commerce system. Accordingly, sellers can maintain their relationship with their customers while gaining profit. Previous studies (e.g., [6,7,14] define trust as an important element in ensuring relationship quality, that is, trust serves as the foundation of any stable relationship. In the context of SNS-based commerce, trust among members is built through interaction. When the trust among members grows, these members perceive SNS-based commerce as a trusted platform that they can use to shop online. Meanwhile, relationship, which is an intrinsic constituent of relationship quality, is built upon communication. In other words, the lack of communication may lead to a poor relationship [15,16]. Therefore, in this study, communication is considered a measure of relationship. Relationship quality is a strong determinant of an individual's s-commerce intention and is related to the perceived usefulness and customer satisfaction with an s-commerce system.

B. IS Success Model

E-commerce is considered a part of IS as it uses information and communication technologies to facilitate, execute, and process its business functions [17]. Therefore, the IS success model [17] has been widely adopted in e-commerce research (Fig. 1). Several minor refinements were applied to the original model to define the possible measures for each of its dimensions and to suit the e-commerce context [10,17]. This model focuses on three variables, (e.g., system quality, information quality, and service quality) interrelated with the use, customer satisfaction, and net benefits of the system.

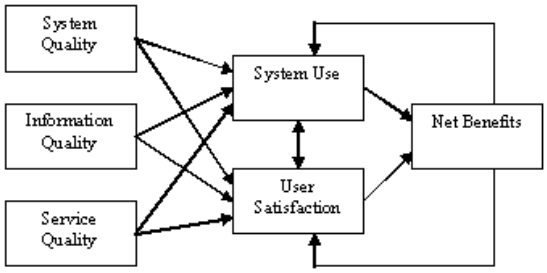


Fig. 1. IS Success Model [10]

Given the ability of the IS success model to measure the e-commerce system, many studies (e.g., [5,6]) have extended and adapted this model to investigate the customer satisfaction with s-commerce by adding the social feature element.

Previous studies have employed various terms to refer to the use dimension, including perceived usefulness. Some have argued that the use dimension represents behavior, thereby making this dimension highly appropriate for process models; by contrast, other researchers contend that the perceived usefulness dimension represents attitude, thereby making this dimension most appropriate for causal models [18]. The high perceived usefulness of e-commerce results in customer satisfaction. Rai et al. [19] validated the above constructs as meaningful measures of IS success depending on the type of delivery. In sum, perceived usefulness is appropriate when considering an attitude derived from perceptions toward past IS use [19,20], whereas the use construct is more appropriate for measuring an actual behavior than the perception toward a behavior [10,19]. Accordingly, we employed perceived usefulness to measure how customers view the potential benefits of s-commerce.

C. Research Model and Hypothesis Development

Our research model was adapted from the IS success [17]. We focused on the relationship among SFQ, perceived usefulness, and customer satisfaction; all the other dimensions of IS success are beyond the scope of our paper. We used customer satisfaction instead of user satisfaction after considering the customer e-commerce satisfaction construct proposed by Molla and Licker [21]. We also used the perceived usefulness construct [18] given that our main objective is to measure attitudes instead of behaviors [19,20]. We added the SFQ element to the left side of the model and excluded the other elements in the IS success model, including system quality, information quality, and service quality, to adapt our model to the objectives and scope of our paper [6,20]. The research model is presented in Fig. 2.

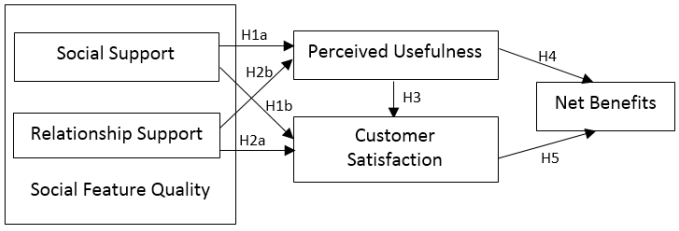


Fig. 2. Research Model.

We greatly appreciate funding received from the Universiti Kebangsaan Malaysia (DIP-2016-033).

SFQ is explained by four constructs:

Social support is related to a social supportive communication in an online context (i.e., SNS). This construct is often measured through information support [5,6,13], emotional support, and normative support [22]. Therefore, we propose

H1a: Social support has a significant effect on the perceived usefulness of s-commerce.

H1b: Social support has a significant effect on the customer satisfaction with s-commerce.

Relationship support refers to the extent to which the members involved in a communication-based relationship trust one another and are committed to their community. *Relationship support* is measured through trust, confidence, commitment [5,6,11], and communication [16]. This construct is also considered as one of the strongest determinants of s-commerce intention that is related to the usefulness and customer satisfaction with an s-commerce [5,6]. Therefore, we propose

H2a: Relationship support has a significant effect on the perceived usefulness of s-commerce.

H2b: Relationship support has a significant effect on the customer satisfaction with s-commerce.

Perceived usefulness refers to the degree to which a user believes that using a system will enhance his/her job performance [19,20]. In other words, customers with a higher level of perceived usefulness experience greater satisfaction [23]. Perceived usefulness also refers to the benefits that users are expecting to receive after using a particular system. In this case, perceived usefulness is concerned with the future (net) benefits of a system. The empirical evidence related to e-commerce [14,24] supports the relationships of perceived usefulness with customer satisfaction and net benefits. Therefore, we propose

H3: Perceived usefulness has a significant effect on the customer satisfaction with s-commerce.

H4: Perceived usefulness has a significant effect on the net benefits of s-commerce.

Customer satisfaction refers to how customers rate their commerce experience in using s-commerce [21]. When customers experience pleasure, they tend to be highly satisfied [20]. In their individual-level analysis, customer satisfaction offers a moderate to strong degree of support for the net benefits of s-commerce [25]. Therefore, we propose

H5: Customer satisfaction has a significant effect on the net benefits of s-commerce.

III. Method

A. Data Collection

A total of 248 respondents participated in our survey. All these respondents were from Malaysia and had previously engaged in online shopping via SNS platforms. We used the snowball sampling technique in selecting our sample and posted online questionnaires on various SNSs, including Facebook and Instagram. This questionnaire was divided into two main parts, with the first part asking for the demographic information of the respondents and the second part asking for the SFQ attribute constructs featured in our model. All questions were measured using a seven-point Likert-type scale ranging from "strongly disagree" (1) to "strongly agree" (7). Upon removing those questionnaires with incomplete and duplicate responses, 220 responses were analyzed quantitatively via structural equation modeling.

B. Data Analysis

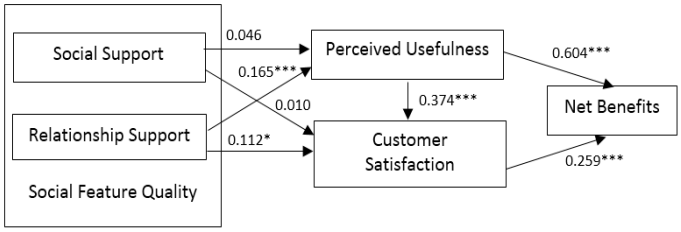
We performed confirmatory factor analysis to validate our model. We then tested the validity and reliability of our measurement items, followed by hypothesis testing analyses.

IV. Results

1) Demographic characteristics: A total of 128 (58.2%) female and 92 (41.8%) male respondents participated in this survey. The majority of these respondents (80.5%) were university students aged between 20 and 29 years. Around 73.2% of these respondents were pursuing bachelor's degree courses. Facebook was the most popular SNS used by these respondents, and only one respondent did not have a Facebook account. Most of the respondents (78%) spend more than 2 hours a day on their SNSs. Therefore, all respondents were assumed to be familiar with using SNS as an online shopping platform

2) Reliability and validity of measurement items: Based on the confirmatory factor analysis, the measurement model exhibited an acceptable to fair fitness with the collected data ($\chi 2$ = 78.822, df = 25, $\chi 2$/df = 3.153, GFI = 0.947, AGFI = 0.893, NFI = 0.974, CFI = 0.982, and RMSEA = 0.078). We then tested the validity and reliability of our measurement items. All constructs are valid with composite reliabilities of above 0.80 and average variance extracted of above 0.50 [26].

3) Hypothesis testing analyses: The findings illustrated in Fig. 3 support hypotheses H2a, H2b, H3, H4, and H5. Specifically, relationship support has a significant effect on the perceived usefulness and customer satisfaction with s-commerce, perceived usefulness has a significant effect on customer satisfaction with s-commerce, and both perceived usefulness and customer satisfaction have significant effects on the net benefits of s-commerce. Overall, SFQ has a significant effect on perceived usefulness (0.175***) and customer satisfaction (0.198***).



*p<0.05, ***p<0.001

Fig. 3. Hypotheses Testing Results.

Social aspect is an essential foundation of s-commerce. We measure SFQ by using the social support and relationship support constructs following the suggestions of previous studies (e.g. [5,6,27,28]). Overall, SFQ shows a significant relationship with perceived usefulness and customer satisfaction with SNS-based commerce. These findings agree with previous studies [8,29] and underscore the importance of social aspect in supporting the interactions and strengthening the relationships among SNS members as they exchange information comfortably and conveniently [5,30].

Although SFQ showed significant positive associations with both perceived usefulness and customer satisfaction with s-commerce, we obtain different results for the individual construct. Surprisingly, only relationship support showed a positive relationship with perceived usefulness and customer satisfaction with s-based commerce, which contradicts the findings of Liang et al. [5], Hajli [6], and Chen and Shen [14] and implies that both social support and relationship support influence s-commerce intention. Our findings show the significant positive relationship of relationship support with perceived usefulness and customer satisfaction, thereby proving that relationship support represents the crucial elements of SNS-based commerce, including consumer trust, confidence, and commitment. This finding is consistent with studies which suggest that after SNS-based commerce consumers trust an online community member, they can confidently engage in SNS-based commerce, begin to realize its usefulness, and consequently increase their satisfaction with this form of commerce [8,11,31]. As a result, the relationship among online community members is strengthened along with their commitment and customer loyalty, which in turn can lead to a boost in sales [6,8].

However, social support quality shows an insignificant relationship with perceived usefulness and customer satisfaction with SNS-based commerce, which aligns with two studies [8,29] but contradicts the results of other studies [5,6,14]. In other words, social support, including emotional and informational support, is not a prerequisite for SNS-based commerce and may instead be related to the quality of information itself. Information overload and difficulty in controlling information may cause confusion among customers [32], thereby raising the concern of whether information can actually support customers when making purchasing decisions in the context of SNS-based commerce. Trust also presents one of the greatest challenges to emotional support [6,14]. Specifically, emotional support is weakened if online community members do not trust one another. In this regard, although the community members show trust to one another, their trust level is low, thereby explaining the insignificant relationship of social support quality with perceived usefulness and customer satisfaction with SNS-based commerce.

The insignificant relationship of social support with perceived usefulness and customer satisfaction with SNS-based commerce does not suggest that social support is irrelevant to SNS-based commerce. Instead, social support complements relationship support, that is, social support serves as a core foundation for the social interaction provided by SNS-based commerce and plays a key role in building relationships among online community members. Consistent with previous studies [7,10,25] we find a positive relationship among perceived usefulness, customer satisfaction, and net benefits of SNS-based commerce. A high level of perceived usefulness leads to customer satisfaction [24], whereas a high perceived usefulness and customer satisfaction maximize the net benefits gained by customers. Therefore, customers benefit from their use of SNS-based commerce when they are satisfied and perceive this system as useful.

V. Conclusion

Our findings contribute to IS theory and practice by providing some guidelines for monitoring and measuring s-commerce social feature quality. Emphasis can be given to a particular measure depending on the study context. However, several limitations of this research must be noted. First, although social support and relationship support have many attributes, we only use certain attributes that we believe to be crucial for the context of our study. Second, we validated our research model by using data from Malaysia. Therefore, our model may have limited generalizability for other countries due to cultural, societal, and situational differences. Third, we performed our research in the e-commerce (C2C and B2C) domain, which is related to s-commerce. Therefore, our study might not represent all domains of s-commerce. Despite these limitations, we believe that our study yields important and reasonable findings that can provide directions to other researchers in the s-commerce and IS-related areas. To provide insightful findings, further research must be conducted with an expanded sample, additional e-commerce domains, and additional SFQ characteristics.

Acknowledgment

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New Approach of Automatic Modulation Classification based on in Phase-Quadrature Diagram Combined with Artificial Neural Network

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***Abstract*—Automatic Modulation Classification (AMC) with intelligent system is an attracting area of research due to the development of SDR (Software Defined Radio). This paper proposes a new algorithm based on a combination of k-means clustering and Artificial Neural Network (ANN). We use constellation diagram I-Q (In phase, Quadrature) as basic information. K-means algorithm is used to normalize data transmitted and pollute by the Additive White Gaussian Noise (AWGN), then the new diagram obtained is considered as an image and coded in pixel before entering in MLP (Multi-Layer Perceptron) Neural Network. Simulation results show an improvement of recognition rate under low SNR (Signal Noise Rate) compare to some results obtained in the literature.**

***Keywords*—Modulations; Artificial Neural Network; clustering; machine learning**

I. Introduction

Automatic Modulation Classification has an important research activity from the last decade [1, 2]. That is due to his civilian and military applications. Principal goal of AMC is to classify different kind of modulations that has been intercepted. With the development of Artificial Neural Network (ANN) [3] and software Defined Radio [4], Liu et al [5] used fuzzy c-means combined with Artificial Neural Network for classify different type of modulations. The model proposed by Liu et al process certain parameters before entering in the neural network in the purpose of modulation recognition. Okhtay et al [6] proposed an algorithm of classification that use a combination of clustering algorithm k-means and k-center using I-Q diagram of constellation for modulation classification. Zhechen et al used K Nearest Neighbor (KNN) combined with genetic algorithm [15] to achieve classification. KNN is one of famous learning algorithms which is categorized into learning and classification phases [14]. The principal problem is to classify modulated numerical signal, at the first step many papers [5,6,15,16] used combination of 2 methods to solve the problem. We proposed a new approach based on I-Q diagram of constellation coded in pixel. At the first step we show that application of k-means algorithm alone in the purpose of normalizing the diagram polluted cannot be used at this point to recognize the modulation used. Then we combined the result obtained with neural network to help in classification but here I-Q diagram of constellation is considered as an image that will be used to feed the MLP neural network. In this paper, we propose an approach of modulation classification using k-means algorithm combined with artificial neural network. The work will be organized as follows:

The model used in this approach will be exposed in Section 2. Section 3 will present our approach of classification. Simulations results will be exposed in Section 4 and Section 5 is for future work and perspectives.

II. Reference Model

We used as reference the model proposed by Liu et al [5] the model is presented in Fig. 1.

In this model modulated signal can be BPSK, QPSK, 8-PSK, 4-QAM, 32-QAM, 64-QAM, etc.

When one of these modulations enumerated is used the signal is corrupted by Additive White Gaussian Noise (AWGN) which can affect the signal and cause an improbable demodulation. At the first step a clustering algorithm (Fuzzy C-Means, K-means, K-center) is used in the purpose of normalizing data corrupted by noise. After that Artificial Neural Network (ANN) is used to recognize the type of modulation used.

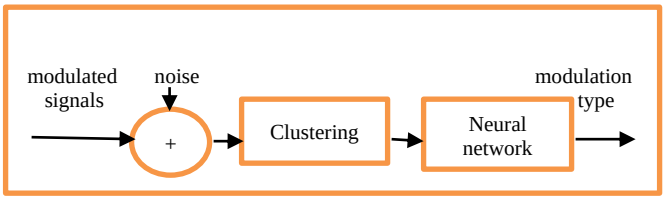


Fig. 1. System Model.

III. Proposed Model of Classification

In our model for classification, we suppose that Gaussian test for detecting single carrier or multiple carrier signal have been done [6]. In our case we are in face of single carrier signal. Clustering algorithm that we used is K-means.

A. K-Means Algorithm

Principle of k-means is to minimize the distortions that we call cost:

$$\cos t = \min_{C}[\sum_{k=1}^{K}\sum_{x_i \in c_k}\|x_i - \mu_K\|^2] \quad (1)$$

Where x_i is a number of clusters C_k and μ_k is the centroid of each cluster C_k.

$$\mu_K = \frac{1}{N_K} \sum_{x_i \in K} x_i \qquad (2)$$

Fundamental purpose of clustering method is to assign observations into cluster. Mobasseri et al [13] show that receptor can use constellation of signal modulated to find the modulation used by emitter. To get the result he just consider the matrix of data X where $X = [x_1\ x_2\ ..\ x_j\ ..\ x_N\ ]^T$. N represents an ensemble of points. $X_j = [x_{ji}\ \ x_{jQ}]^T$ where x_{ji} is the component "in phase" and x_{jQ} id the component in "quadrature".

When a signal modulated is for example 16 QAM with N = 10000 and S/N = 4 dB we get the following result in Fig. 2.

When a signal is transmitted and polluted by noise, we get the following result in Fig. 3.

After application of k-means clustering we have the result in Fig. 4.

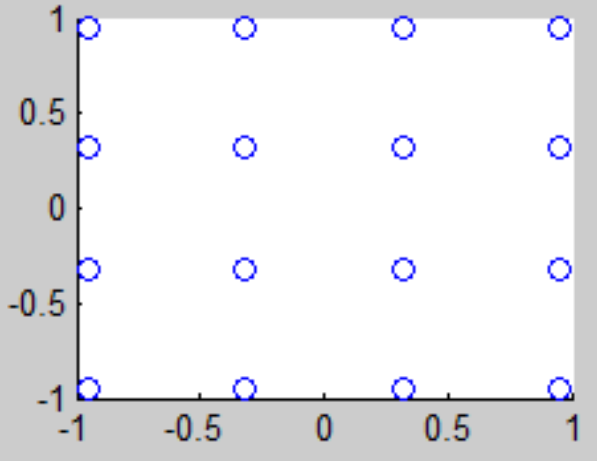


Fig. 2. Transmitted Signal.

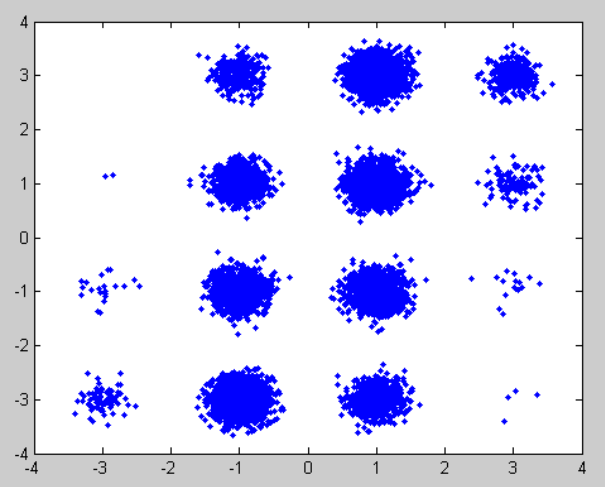


Fig. 3. Received Signal Polluted by the Noise.

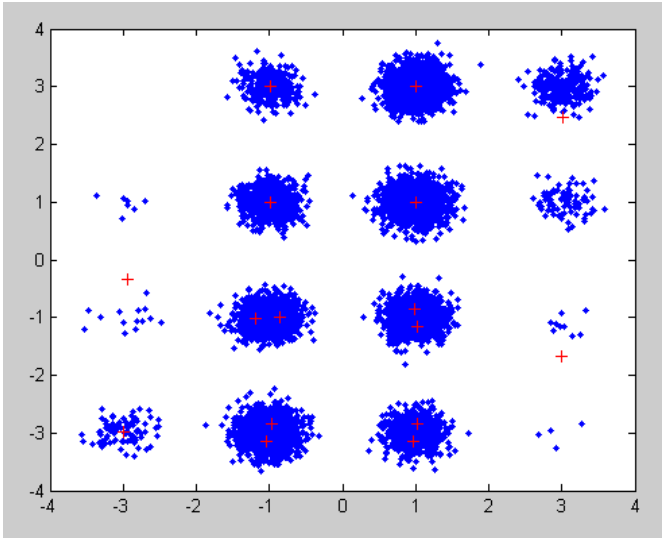


Fig. 4. Application of K-Means.

B. *Artificial Neural Network*

We use a Multilayer Perceptron (MLP) Neural Network [10] to solve our problem. In our case we have 7 classes corresponding to our 7 modulations chosen which are the most used in many papers [5,6,8,11,12,15,16]. As each modulation constellation can be set on a matrix 7x7, we set 49 input nodes. In addition, as we have 7 modulations to classify, the network contains 7 output nodes and the hidden layer has 98 nodes. Our MLP is presented in Fig. 5.

Activation function for neural network is "softmax function"

- Class1 ➡ [1000000] (16-QAM)
- Class2 ➡ [0100000] (4-QAM)
- Class3 ➡ [0010000] (16-PSK)
- Class4 ➡ [0001000] (8-PSK)
- Class5 ➡ [0000100] (BPSK)
- Class6 ➡ [0000010] (8-QAM)
- Class7 ➡ [0000001] (32-QAM)

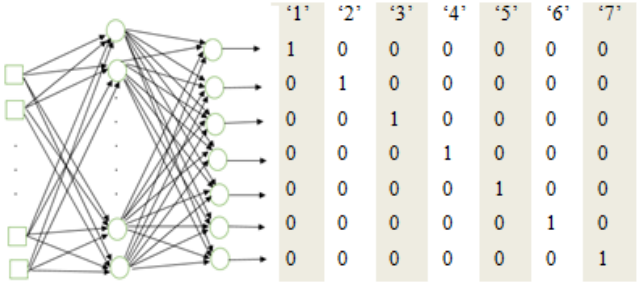


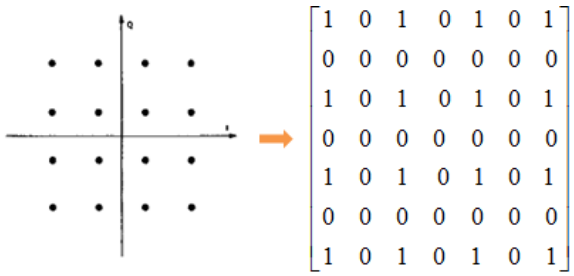
Fig. 5. Multi-Layer Perceptron.

$$y_i = \varphi(v_i) = \frac{e^{v_i}}{\sum_{k=1}^{M} e^{v_k}} \qquad (3)$$

C. Model for Modulation Classification

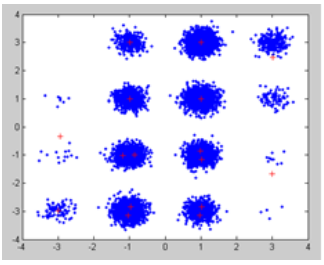
Our model is a case of supervised learning where different modulations in use are known by receptor. I-Q diagram of constellation will be used as an image coded in pixel. For example, a constellation of a signal modulated in 16-QAM in our model called ANNG (Artificial Neural Network imaGe) will be coded as it is showed in Fig. 6.

Signal modulated in 16-QAM at S/N = 4 dB after applying k-means algorithm and coded will be presented as it is on Fig. 7.



$$\begin{bmatrix} 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 & 1 \end{bmatrix}$$

Fig. 6. 16-QAM Constellation Coded.



$$\begin{bmatrix} 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 0 & 0 \end{bmatrix}$$

Fig. 7. 16-QAM Constellation Polluted by Noise Coded after Application of K-Means.

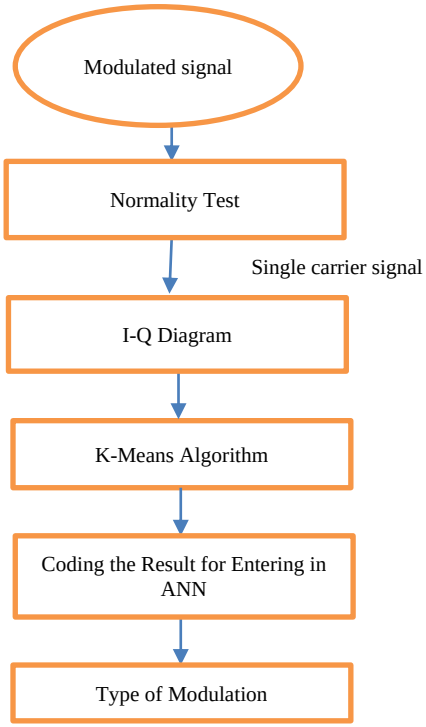


Fig. 8. Proposed Algorithm ANNG.

This result shows that for our model of classification constellation diagram I-Q can be considered as a matrix 7x7.

D. Algorithm Diagram for Modulation Classification

Proposed algorithm is presented in Fig. 8.

IV. Results and Discussions

In this part, we will show the results of our simulations. Table I present order of entrance in neural network.

Neural network will pass by a learning phase where epoch will take the value of 10,000 at the first stage and we will be increased to check for learning level of our model. We take the learning rate at $\alpha = 0.9$ ($0 < \alpha \leq 1$) because if that value is low neural network will converge slowly [7]. Our simulation has been done with these parameters:

- PC running Windows 10
- 8 Gb of RAM
- Processor Intel core i5 7th generation
- Programming language is MATLAB 2013a

In most of results found in different papers [5,6,8,13,15,16] problem occurs when we face low value of S/N. That is why we used to test our model at S/N = 4 dB. Fig. 9 presented an example of results.

Table II summarizes our simulation result.

This gives an average error rate for each epoch in Table III.

We know that an epoch corresponds to learning on all the data. The curve in Fig. 10 shows us that higher the number is better the accuracy is, which proves that our neural network behaves normally (convergence) with respect to the learning phase. But we note that from 4,000,000, the value of the number of iterations of our model has reached the critical point.

TABLE. I. Modulations Chosen for Classification

Order	Diagram I-Q pollute by noise
1	16-QAM
2	8-PSK
3	4-QAM
4	BPSK
5	8-QAM
6	16-PSK
7	32-QAM

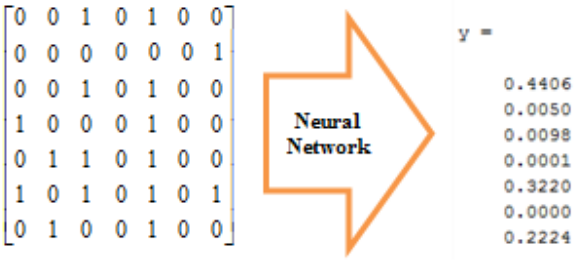


Fig. 9. An Example of Test Results.

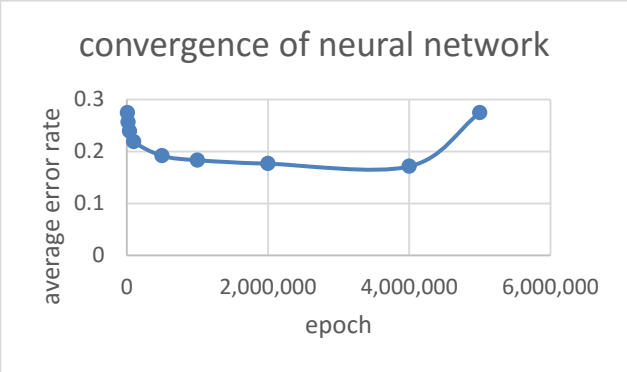


Fig. 10. Convergence of the Neural Network.

Tables II and III shows that our model gives good results on average percentage of total recognition of our seven modulations chosen is 82.85% at the cycle of iteration equal to 4,000,000. Taking into account our chosen modulations, the weak recognition results are for 16 QAM and 16 PSK modulations. This is because: in our representation of the constellation of these modulations in the form of 7x7 matrix, there are many points more precisely 8 out of 16 points are placed at the same location on the constellation diagram presented in Fig. 11.

But it is on the basis of these constellations that our supervised learning happens with the neural network, which explains why the neural network sees practically in equal proportion:

- 45.66 % for 16 QAM
- 53.45 % for 16 PSK

TABLE. II. RESULT OF THE NEURAL NETWORK FOR EACH MODULATION ACCORDING TO THE EPOCHS

Epoch / Modulation	10000	100000	2000000	4000000	5000000
16 QAM	0,4406	0,497	0,4789	0,4566	0,4406
BPSK	0,8124	0,8381	0,913	0,9291	0,8124
8 PSK	0,9914	0,9894	0,991	0,9917	0,9914
8 QAM	0,6541	0,83	0,9109	0,9193	0,6541
16 PSK	0,2333	0,35	0,5011	0,5345	0,2333
4 QAM	0,9506	0,9653	0,969	0,9687	0,9506
32 QAM	0,9946	0,9982	0,9997	0,9998	0,9946

TABLE. III. AVERAGE ERROR RATE OF RECOGNITION FOR EACH EPOCH

epoch	10000	100000	2000000	4000000	5000000
	0,5594	0,503	0,5211	0,5434	0,5594
	0,1876	0,1619	0,087	0,0709	0,1876
	0,0086	0,0106	0,009	0,0083	0,0086
	0,3459	0,17	0,0891	0,0807	0,3459
	0,7667	0,65	0,4989	0,4655	0,7667
	0,0494	0,0347	0,031	0,0313	0,0494
	0,0054	0,0018	0,0003	0,0002	0,0054
Average	**0,2747**	**0,2188**	**0,1766**	**0,1714**	**0,2747**

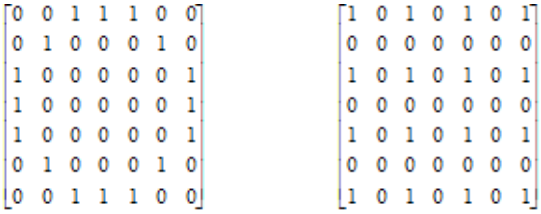


Fig. 11. Representation of the Constellations of 16 PSK and 16 QAM Modulations in Matrix Form.

Apart from these two modulations the results given are satisfactory. Table IV summarizes the results of recognition of the other modulations still at the cycle of iteration equal to 4,000,000 which gives our best results.

A. Comparison with other Results

In the field of automatic modulation classification, the comparison directly with other results is difficult as was mentioned in [13, 16] this is because:

- each author uses certain parameters for their algorithms which are different from each other.
- there are no standard databases of modulations that each author must use in order to facilitate comparisons.

In case of comparing our results to some of the results presented in the literature, we choose four modulations (BPSK, 8 PSK, 4 QAM, 32 QAM) which are the modulations frequently used in many papers.

Table V presents the main results of some methods proposed in the literature.

TABLE. IV. RESULTS FOR FIVE MODULATIONS

Modulations	Percentage of recognition
BPSK	92,91 %
8 PSK	99,17 %
8 QAM	91,93 %
4 QAM	96,87 %
32 QAM	99,98 %
average	**96,17 %**

TABLE. V. COMPARISON WITH OTHER METHODS

Modulation / Method	BPSK	8 PSK	4 QAM	32 QAM	average
Fuzzy Clustering Method (FCM) of Liu et al	100 %	95.8 %	93.6 %	16 %	**70.6 %**
Clustering combined with ANN of Liu et al	100 %	100 %	100 %	73.6 %	**91.2 %**
k-means and k-center of Ohktay et al	100%	87 %	96 %	95%	**94.5 %**
KNN of Zhechen et al	100 %	82.73	59.99 %	60 %	**75.68 %**
ANNG our method	92.91	99.17	96.87	99.98	**97.23 %**

As presented in Table V, our method shows an improvement in term of recognizing different modulations used at low S/N particularly at 4 dB.

V. Conclusion

In this paper, we presented a neural network-based modulation classification approach that we called ANNG (Artificial Neural Network imaGe). The originality of this approach is that it considers the I-Q diagram as an image that will be coded as a pixel. In the literature the input parameters of the neural network are calculated before entering in the neural network. Our new approach doesn't need to calculate certain value before entering in the neural network but just consider I-Q diagram as one block of image polluted by noise. At the first hand we use k-means clustering to normalize the diagram polluted by noise and after that use MLP to take a decision about the modulation used. Future work can be to reduce processor time consuming of our model [9] and improve percentage of recognition modulation. In this case we will try constructing a DNN (Deep Neural Network) of our model.

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User Perspective on External Value Creation Factors in Indonesia e-Commerce

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***Abstract*—Value creation is very important for the e-commerce companies in order to reach customers and increase company's value in the view of customer. Value creation mostly developed based on internal factor of the company. This statement is supported by many studies that researched on value creation from within the company. The purpose of this research is to find out customer's perspective on the external environmental factors that can affect the value creation of e-commerce companies, especially in Indonesia. This research uses primary and secondary methods in data collection. Questionnaire is used as primary research methodology in this research to gather data from e-commerce users. For the secondary method, literature reviewed from previous research and existing journals is used. The results of this research are the statements from respondents regarding external environmental factors that can be classified on 5 (five) factors: Government policy and legal, telecommunication infrastructure, financial and capital investment, physical environment, and payment system.**

***Keywords*—External environment factors; e-commerce; user perspective; value creation**

I. INTRODUCTION

E-commerce in Indonesia has developed and improved in many forms of business model. The development of this industry can be seen from the amount of investment in the e-commerce industry of US $ 2.5 billion over the past three years It is based funding of foreign investment in Indonesia from 2015 to 2017, with 18 million customers in 2015 and is expected to increase to 119 million by 2017 [1]. The great public interest in utilizing e-commerce services is influenced by the characteristics of consumers in Indonesia, which can be classified into six, namely: Willingness to pay more for certain brands, purchasing similar goods, preference for purchasing package goods, high frequency of purchases and social media influence [2]. The increasing trend of people to buy online is causing a shift in industrial structure.

Companies are no longer determining the business model based on the conventional experience or management's will, but they must be able to adjust to the character of local community and culture. Business actors who are involved, both buyers and sellers, use the internet-based technology to carry out their transactions. The use of technology and information system in e-commerce services is featured on many online shopping platforms or e-commerce websites. Various types of business models have been produced based on a study of e-commerce in Indonesia. Most e-commerce models in Indonesia consist of five types: Business to Customer (B2C) or online marketplaces, Customer to Customer (C2C), Business to Business (B2B), flash site websites, and sales sites directly through brand websites own.

The various forms of e-commerce models require the companies to make innovation and create certain values that can provide benefits to the customers. Based on the literature studies, many researches were conducted to study the value creation in e-commerce from factors inside the company (internal) only rather than looking it from the external factors. It is a background reason for this research, which is to identify the external factors that may influence the value creation in e-commerce companies, especially in Indonesia. These external factors will certainly create more opportunities or otherwise, create potential risks for the sustainability of the business, and so business strategies are needed in dealing with the arising external factors.

The study focuses on several Indonesia's e-commerce with high visit rates, namely, Tokopedia, Lazada, Blibli, Elevenia, and Bukalapak as listed in Table I.

This research was conducted using primary data and secondary data. The primary data was obtained from the results of the questionnaire to the respondents who the e-commerce users by are asking several closed-type questions, while the secondary data was obtained through literature study or the results of previous research. Limited time, cost and location were the challenges in the research process to obtain an adequate number of respondents.

The proposed of this study is to find out customer's perspective on the external environmental factors that can shape the value creation of e-commerce companies. The results would later be analyzed and processed in order to obtain an evaluation in the form of external factors that shape value creation in e-commerce companies in Indonesia.

TABLE I. E-COMMERCE SERVICE IN INDONESIA

	E-Commerce				
	Tokopedia	***Lazada***	***Blibli***	***Elevenia***	***Bukalapak***
Product categories	General retail	General retail	General merchandise with a focus on electronics	General retail	General retail
Number of sellers(B2C) and/or (C2C)	1 million	15,000	6,000	30,000	1.3 million
Business model	C2C, B2C	B2C	B2C	C2C, Flash sales	B2C, C2C
Monthly visits (million)	46.5	51	25.7	34.6	28.3

II. LITERATURE REVIEW

A. E-Commerce Business Model

From 1989 to the present, the Internet has provided many changes to many e-commerce companies in the world in managing and restructuring new systems in business to achieve their company's vision. This thinking model has flowed into a business model for each e-commerce company. In a sense, a business model is a concept to carry out the business functions of a company. The concept of business models challenges traditional theoretical assumptions about both value creation and value capture, two terms often used to describe the models [3]. However, business models are the key factors that distinguish successful and unsuccessful e-commerce companies in developing strategies to reduce costs while increasing revenue will be profitable [4]. The e-commerce company, especially in Indonesia should be considered the importance of creating innovative business models.

The biggest challenge facing most companies is not how to imitate or estimate the best e-commerce business models in their industry but how to fundamentally change the traditional business mindset [5]. Information Technology (IT), and especially web technology has great potential to enable significant innovation in business processes, products, and services of the company, leading to considerable business performance improvements [6]. In study [7] revealed that to outperform competitors in the long term, it needs to consider three main steps, including:

- provide the right resources and are also the most efficient transaction at any given time.
- renewing the peculiarities to prevent the threat of competition.
- redefining the business model effectively in accordance with the business strategy.

B. E-Commerce in Indonesia

E-commerce is a new technology that has a remarkable appearance. It can be used for novice entrepreneurs and corporate businesses. In addition, e-commerce also changes the culture of competition and business by utilizing extraordinary digital technology [8] [9]. Indonesia is one of the developing countries with the 6th largest number of internet users from 25 developing countries, namely 123 million people based on information from the Ministry of Communication and Information of the Republic of Indonesia on November 24, 2014. The number indicates that 46.42% of the Indonesian population is connected to the internet. In other words, based on the results of research by Indonesia Investments that e-commerce (which is a group of Small Medium Enterprises) has contributed 60 percent of Indonesia's gross domestic product and created employment for nearly 108 million Indonesians [10]. This is evidence that the economic pressure is increasing annually can be both opportunity and challenge to related bodies and institutionalized in Indonesia to improve their business, legislative, and IT infrastructure for a bright future.

The e-commerce growth in Indonesia over the past five years was mainly driven by four structural changes in the industry, including [11]:

- Availability of low costs to support increased smartphone penetration.
- Creating e-commerce value to facilitate the middle class whose income tends to increase.
- Facilitating a new digital payment model that is fast and easy. Payment infrastructure must be available for customers to transact online.
- Providing direct foreign investment opportunities on e-commerce platforms, especially through significant partner relationships or joint ventures.

Data market has proved, the evolution of Indonesia's market growth by 60-70 percent per year since provides opportunities for Indonesian e-commerce companies to their business [12]. Therefore, this momentum must be maintained and continues to be improved by both the government and e-commerce companies.

C. Value Creation

Study in [8] "Value Creation in E-Business" has been analyzed using a business model on 59 (fifty-nine) American and European e-businesses. The business model is defined in this research as a mechanism that describes transaction structure, content, and governance that aims to create e-business value. It is defined as an important value for the exploitation of the company's business opportunities. Based on this research, four important values are found, namely: novelty, complementarity, efficiency, and locking. This value is an important factor in value creation for e-commerce.

The study "E-commerce developments and strategies for value creation: The case of Russia" added ease of use, accessibility, ease of search and trust in their source of value creation with efficiency, lock-in, complementarities and novelty along together as interactivity of value creation [4]. The study labeled it as Internal value drivers. Each eight of e-commerce value driver are given as to how some Russian firms are using e-commerce to create value by including these drivers in their business models. External environment also mentioned in this study, see sub section D for a general representation of these models.

In addition, value creation itself is not only to exploit business opportunities but can act as a business model strategy that gets financial benefits. To investigate the e-commerce business model that is beneficial, one of which is in Poland which includes 150 business marketplaces, customer to customer, and customer to business [13]. The results of this study are statistically significant value creation business models affect the sales ratio. The results also show that three important factors in value creation (efficiency, novelty, and locking) are closely related to financial performance.

D. External Environment Factors

From the results of study in [4], stated that external environment factors play an important role in determining how e-commerce produces value creation. The success of an e-commerce company in Russia, is an e-commerce company that has a business model that pays attention to external environment factors and value drivers to increase efficiency in transactions and revenues by reducing transaction costs and increasing social perception. External factors that can form business strategies for e-commerce companies are financial resources; availability of computers and internet connections; telecommunications infrastructure; computer programming resources; external physical environment; law, government, political and economic stability; internet security and payment system.

In the previous research conducted in [14] using PEST (Political, Economic, Social and Technological) analysis as an external environment factor that would generate opportunities, threats and business implications for e-commerce. External environment factors must be considered before carrying out the process of formulating the company's strategy so that it can avoid undesirable strategies and increase the likelihood of the company to growth. External factors are Governmental environment; Domestic politics; International politic; Economic development; Arid industry sector policies; Regional economy; Monetary and fiscal policies; Social environment; Cultural environment; Demographic environment; Natural environment; Processing technology; Information technology.

III. Research Methodology

This research had two phases in this methodology. First, by doing systematic literature review from others reliable journals as references to find external value creation factors based on external environment according e-commerce in Indonesia. Second methodology in this research is questionnaires, the questionnaires distributed to respondents where they had used e-commerce in Indonesia. The proposed of this questionnaire is to find user's perspective from external environment in Indonesia's e-commerce. With this approach the relationship between concepts expressed in the data and drawing conclusions from the evidence [15]. Environment factors were defined in this research as factors that shape the development of e-commerce. External environment factors in previous study [4] are used as references in choosing external factors that have some similarity between Indonesia and Russia.

When doing research, questionnaire has been delivered to random respondents that been used e-commerce in Indonesia. The total respondents are 139 people. Many of them are person above poverty line. The successful of emerging e-commerce cannot be separated from people with good financial resources as its customers. This questionnaire filled with what respondents' opinions about external environment when using e-commerce. Likert scale is used through this questionnaire; by using score range (1 to 5) from strongly disagree to strongly agree. After data were obtained from respondents, the data will be analyzed and make conclusion from it. Analysis about the data will produce the prospective user how external environment factors in Indonesia affect value creation within e-commerce.

Questionnaire is the preferred method of this research due to some reasons. One of the reasons is because it is relatively high response instead of interview method which could difficulty in conduct face-to-face and low response rates in the obtained data. The effort of delivered questionnaire occurred in 2018. It took two days to collect the result. The questionnaire itself using Indonesian, if using English as its questions, respondents were difficult to understand about questions. It because most respondent unable to understand English. Furthermore, by this questionnaire will able to make comparison regarding perspective between one respondent to others.

IV. Finding and Discussion

A. Questionnaire Results

Based on 139 data were collected of which then studied and analyzed one at a time to find out the attitudes and behavior of respondents in responding to the external factors that can shape the value creation in e-commerce companies in Indonesia. As an overview, there are 2 (two) out of 139 respondents were not using e-commerce due to their preference in conventional transaction instead of digital transaction, therefore only 137 respondents calculating in this research.

An analysis was carried out to identify the 137 respondent's status. Fig. 1 presents, most of the respondents are over years old 43.9% and working as private employees 63.3%, with background education is undergraduate or bachelor's degree 66.2%.

The next information that can be seen is that most e-commerce sites that were used or visited by the respondents are Tokopedia (123 visited) followed by Lazada (89 visited) with the percentage as shown in Fig. 2.

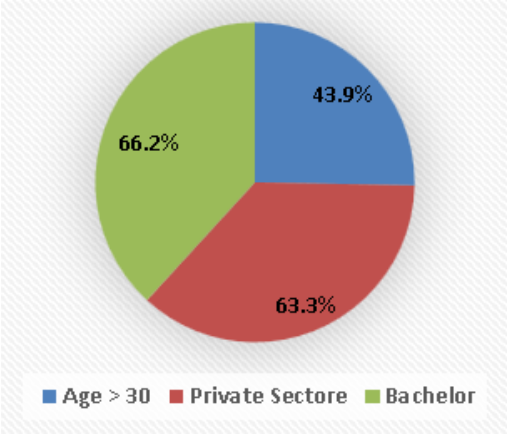

Fig. 1. General Information of Respondents.

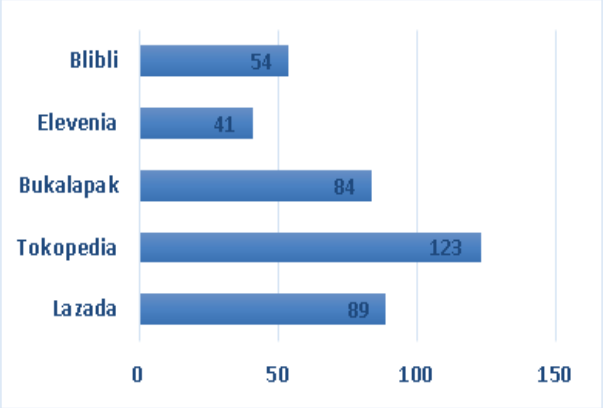

Fig. 2. E-Commerce Sites used / Visited.

TABLE II. QUESTIONER RESULTS

External Environment	Response (%)		
	SD + D	*N*	*SA + A*
Government Policy and Legal			
Legal certainty in e-commerce transaction	7	21	72
The tax impose for e-commerce business	26	33	41
Finance and Capital Investment			
Foreign investment influencing user visit e-commerce sites	31	47	22
Customer preference using e-commerce mostly when receive salary	28	36	36
Customer preference most using e-commerce at national holiday	27	31	42
Customer preference using installment payment method	48	26	26
Physical Environment			
The distance of the shopping store from user location	37	28	35
The traffic route to the shopping store	24	26	50

Then, the next analysis process is to look into the answers of respondents regarding the external factors which become the focus of this research. The results of answers using the Likert method will be classified according to the questions and the most answers given by the respondent. The following is summary of the answers to questions using the Likert method based on the most given answers by 137 respondents which is classified into: Agree (A), Disagree (D), Neutral (N), and Strongly Agree (SA) responses. Table II presents the questioner results of government policy and legal, financial and capital investment, and physical environment. Meanwhile, the results of the telecommunication infrastructure and payment system will be described in section D and F.

B. Government Policy and Legal Factors

As a means of selling and buying products by digital, E-commerce transactions in Indonesia must comply with both Law No. 7 of 2014 concerning Trade and Law No. 11 of 2008 related to Electronic Information and Transactions - ITE. The existence of regulations that provide legal certainty for users and e-commerce company will increase the consumers trust in online transactions. It is one of the expected concerns of the respondents with 72% of respondents answering strongly agree and agree to legal certainty to protect consumers. The significance of these regulations makes the e-commerce company to be careful in creating their systems and also when maintaining the quality of products offered. As the result, e-commerce business company can compete in a healthy manner when offering new innovations in reaching the customers without violating the existing regulations.

The development of e-commerce business in Indonesia also indirectly changes the business behavior from conventional to the digital one. The digital transaction draws attention of the government to impose taxes on the sale of goods/services in e-commerce transaction. This tax imposition also applies in many countries other than Indonesia. This is the basis of this research, that whether the application of e-commerce tax will affect the users of online services or not. Most respondents answered neutral (33%) in responding to this tax regulation. However, the proportional most answer was 41% people answered Strongly Agree and Agree. Hence, the tax regulations that will be applied should be a concern for e-commerce businesses to implement their business strategies, especially in planning product costs and prices.

C. Financial Factors and Capital Investment

Ownership of foreign shares in e-commerce companies is one of the alternative financing in developing a business. The large population of Indonesia as well as the increasing interest of the public in using online transactions has attracted many foreign investors in e-commerce business in Indonesia. One of the widely known foreign investors in Asia is Alibaba group. This company has made its investment in the development of Tokopedia and Lazada in Indonesia. This research also attempts to find out whether the foreign investors are one indication of users for visiting the e-commerce sites. A number of 47% respondents answered Neutral, while it is if measured proportionally, the respondents who answered Disagree were more than those who answered Agree. Accordingly, the respondents generally feel that they do not need to know much

about who the investors behind the e-commerce are. This condition certainly will give benefits and opportunities for the local investors to be able to develop e-commerce in their country and compete with the foreign e-commerce sites.

Another object of this research in financial factors is the availability of fund of the consumers in conducting online transactions. For those who have stable jobs, their availability of funds is when they receive salary, as companies in Indonesia commonly pay employee salary at the end of the month. This phenomenon turns out to be a regular activity in using the e-commerce. Based on the proportional of data obtained, 36% respondents answered Strongly Agree and Agree. This consumer behavior will surely affect the implementation of a good operational management for e-commerce companies at the end of the month.

Other condition is related to national holiday which offer many discount or sale to the e-commerce customer. Total of 42% respondent Strongly Agree and Agree to using e-commerce at the national holiday. This condition could be one of consideration for e-commerce company to provide any promotion for the customer. Customer behavior that tends to make transactions during the payday also follows the payment system behavior. As many as 48% respondents said they did not agree to make installment payments, while those who agree to use credit cards were only 19 respondents. It can be assumed that e-commerce customers tend to make transactions in cash and avoid paying the interest from credit or installment method.

D. Telecommunication Infrastructure Factor

Factors of telecommunication facilities availability such as the Internet are very influential for a smooth operation of the Indonesian e-commerce. Based on questionnaire result, the price (34%) has proved that an important factor according to respondents in e-commerce transactions, in addition to provider and internet network about 31% (see Fig. 3). Therefore, telecommunication business company are expected to be able to develop an effective and efficient quality of systems both in maintenance and repair for them to provide economical prices for the customers in transactions. E-commerce Company may also consider using a telecommunication provider that offers data connection speeds at a competitive price.

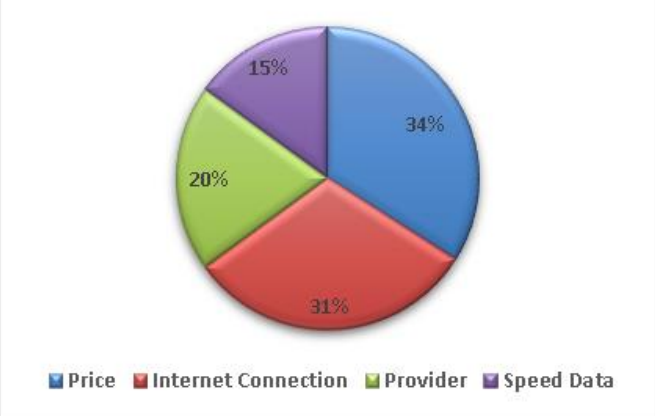

Fig. 3. The Most Important Factor of Telecommunitaion in E-Commerce.

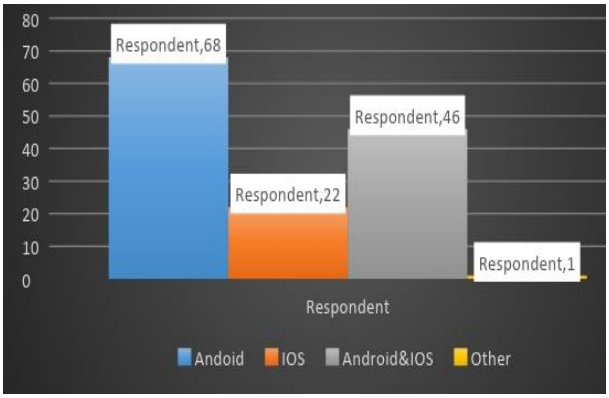

Fig. 4. The Result of Operation System used in E-Commerce.

Other factor of this research is the operational system used in transactions. As presented in the Fig. 4, a total of 68 respondents answered that they use Android system for online transactions and followed by Android & IOS about 46 respondents. Both operational systems are in great demand today, especially for Indonesian consumers. The convenience, speed and economical price should be considered by the operating system developers in developing their newest products.

E. Physical Environment

The physical environmental factor in this study is the movement of people from one place to another. Other place in this case is the shopping centers or shops which are physically existing. Consumers behavior who made online transactions, indeed are not directly influenced by the distance of their location to the conventional shopping centers. As many as 38 respondents stated Neutral, while the proportion of the answer in category Disagree and Strongly Disagree are 51 people and the respondents who answered Agree and Strongly Agree are 48 people. Although the majority answered Disagree, but with a close difference in results, it can be observed that the existence of conventional stores that are far from the location of consumers will affect the number of store visits and therefore, the consumers turn to e-commerce.

Other things related to this physical environment can also be observed from route condition to the shopping center. Relatively congested roads in Indonesia, especially in the capital city of Jakarta, has made the consumers reluctant to go to the shopping centers/shops and so that they chose to shop online instead. Based on the results of the questionnaire it was found that 28.5% of the respondents answered Strongly Agree that traffic jams were the reason for e-commerce transactions.

F. Payment Method

Many payment systems can be made on e-commerce starting from internet banking, ATMs, through physical outlets or by Cash on Delivery (COD). E-commerce business company can also complete their payment method though payment gateway system to various merchants. From the results of the respondent's answers, it was found that 70.8% of respondents used transfer payment via internet banking in their transactions. Finally, guarantee of trust and success of the transaction through internet banking is an important issue for the consumers in making payments. E-commerce business

company may cooperate with financial institutions such as Banks or companies providing electronic payment instruments that guarantees convenience and timeliness of payments.

V. Conclusion and Future Research

This study aimed to find out the statements of respondents about external environmental factors that could be used as suggestion to the e-commerce companies in developing their companies, especially in Indonesia. External factor has proved that Government policy and legal, telecommunication infrastructure, financial and capital investment, physical environment, and payment system shape the value creation of e-commerce companies in Indonesia. The presence of this study expects readers and e-commerce in Indonesia to know that external environmental factors also influence the value creation in determining the company's strategy when facing environmental changes from outside the company. However, this study only looked at e-commerce in Indonesia namely, Elevenia, Lazada, Blibli, Tokopedia and Bukalapak, Elevenia, so these findings may not refer to e-commerce in other countries.

Further research is needed to discuss these external environmental factors based on the conditions of the area or the environment of each user. For the researcher, they can use this study as references to see the important role of external factors that can affect value creation of e-commerce.

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Double Diode Ideality Factor Determination using the Fixed-Point Method

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***Abstract*—In this paper, we are interested in the diode ideality factor study of the double exponential equivalent model, based on the properties of the fixed point method. The optimal choice of this factor will improve the photovoltaic installation profitability. The diode ideality factor is a crucial parameter to describe solar cell behavior. Different methods have been elaborated to determine its value; some of them are analytical as Lambert function and others are direct as the normal method of the coordinates of the parameters. In our case, we applied the fixed point method which is an iterative algorithm to solve non-linear equations. The values obtained by this method are compared with the calculated values achieved by other methods to prove its significance and effects.**

***Keywords*—Ideality factor; fixed point; double diode; solar cell**

I. Introduction

The solar cell mathematical modeling is a crucial and indispensable step for the photovoltaic generator performance study and any optimization operation. Mostly the photovoltaic cell is represented by an equivalent electrical circuit whose parameters are based on the current-voltage characteristic. In this context, several methods have been investigated to determine the equivalent circuit parameters mentioned above. The diode ideality factor is an important parameter in the electrical behavior description of the p-n junction solar cell. This empirical factor indicates the material quality; it is due to the atomic interaction of the semiconductor-metal interface. It reports excess recombination in the depletion zone [1], [2]. This factor depends on the operating conditions of the device. In the case of minority carrier scattering, the Shockley scattering theory gives approximately the value of the ideality factor of the diode between 1 and 2 for silicon diodes in the case of recombination in the charge region of space [1, 2]. Theories have predicted n = 2 at high injection levels as the recombination density increases [3, 4]. The increase in the quality factor of the diode affects the quality of the diode and the point of maximum power in the operating area. The diode ideality factor depends on weather conditions such as temperature, lighting and also voltage [5]. Several methods have been developed to extract the value of the diode ideality factor based on the exponential diode model, which explains the introduction of different values of the diode ideality factor from direct methods such as direct measurement [6], the method of the series of variable resistances [7], the normal method of the coordinates of the parameters [8, 9]. Other analytical methods have been developed such as the techniques for determining the diode ideality factor of solar cells were given in [8] [9] and special transfusion theory (STFT), which is a tool for solving transcendental equations [10-14], solutions based on this method are accurate and analytical. However, the exponential diode model is considered insufficient to correctly describe the two linear regions of the voltage-current characteristic of the photovoltaic cell; so we consider the two-exponential model to figure out this problem as in [15]. The main objective of this study is to propose another method to determine the value of the diode ideality factor (n) using a fixed-point iterative method that is applied to solve non-linear equations. This method is applied to the double exponential mathematical model given in equation (1). Recently, there is strong competition in the field of photovoltaic panels manufacture, we determine an optimal value of diode ideality factor which represents the diode conformity to a pure thermo-conduction to improve the process Manufacturing.

This paper is split into four parts: Section 2 is a presents the fixed-point method and its applications to our case of a double diode solar cell. Section 3 shows some simulation results and discussion to determine factor ideality of a grey solar cell studied in [5]. The final section gives some concluding remarks.

II. Fixed Point Method

A. Presentation

The fixed point method is a numerical technique; it has been used to solve the problems of nonlinear equations and implicit functions. This method has been cited in several fields such as chemistry and biology as well as others, the simplicity and usefulness of this method have prompted many researchers to extend it further.

The iterative process is a crucial principle in computer science. It is principally used to find equations roots, solutions of nonlinear equations and differential equations, and so.

The fixed-point method generally devoted to solve nonlinear equations expressed as $y(x) = 0$, where y is a nonlinear function of a variable x. The method is based on an iterative scheme to lead a given convergent sequence towards a fixed point x of its corresponding function, this fixed point is the solution of the equation $y(x) = 0$.

This method is defined as follows:

- Convert the equation $y(x) = 0$ into the form $x = F(x)$.
- Elaborate an iterative procedure to implement the corresponding sequence.

- Start with an initial guess $x_0 \approx r$, where r is the initial solution of the equation.
- Iterate the procedure $x_{n+1} := F(x_n)$ for any index n.

A Fixed-point technique is one of the methods to figure out nonlinear equations. As an example of the complex nonlinear equations translating some physical behavior, the one studied in [16]. In our case of the exploitation of the totality of the current-voltage measurements coming directly from a PV module, we analyze the equation (1) to solve it using the fixed-point method to pick out the diode ideality factor of the solar cell component.

In this paper, we propose a fixed-point method to solve the nonlinear equation (1). Since, others seem to be more complicate to implement directly. As an example, we find those used in "STFT" [6] and "W-function" [10, 17].

B. Application to the Solar Cell Model

In this work, the fixed-point method is used to solve the nonlinear equation of the double exponential electric model of Fig. 1. The model has seven parameters (I_{ph}, I_{01}, I_{02}, n_1, n_2, R_s and R_{sh}). This method has shown its efficiency and interesting performances in different disciplines. As an example; it was used to calculate the two-dimensional magnetic field in a device with magnetic hysteresis that was modeled by a simple analytical scalar model. This approach allowed easily the computation convergence [18].

The seven parameters knowledge allow controlling the solar cell performance and make the maximum power point (MPP) extraction enabled in the photovoltaic generator.

Therefore, the identification of the photovoltaic cell parameters is a crucial step for the photovoltaic generator performance study and output optimization. Unfortunately, equation (1) is an implicit transcendental nonlinear equation. This implicit form increases the complexity of parameter extraction and PV systems. To solve this equation, we propose an iterative approach to find the roots and solutions of this nonlinear equation.

The double junction photovoltaic cell model represents more closely the observable effects on the device under various lighting conditions.

The solar cell electrical behavior, represented by two diodes, is described by the equation (1) [5]:

$$I = I_{ph} - I_{01}\left(e^{\frac{V+R_sI}{n_1V_{tn}}} - 1\right) - I_{02}\left(e^{\frac{V+R_sI}{n_2V_{tn}}} - 1\right) - \frac{V+R_sI}{R_{sh}} \quad (1)$$

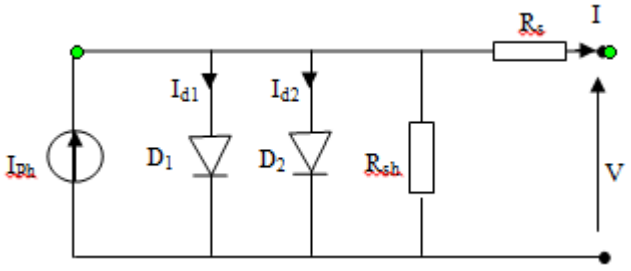

Fig. 1. Equivalent Electrical Model of the Double Junction Photovoltaic Cell.

Where:

- The thermal voltage is:

$$V_{tn} = KT/q \quad (2)$$

- I_{01},I_{02}: saturation current in the diodes D_1 and D_2.
- n_1, n_2: the junction ideality factor.
- I: supplied current by the cell when it operates as a generator.
- V_{tn}: voltage at the terminals of a cell.
- I_{ph}: the cell photo-current; it depends on the illumination and the temperature.
- R_{sh}: shunt resistance characterizing the junction leakage currents.
- R_s: series resistor representing the various contacts and connections resistances.
- K: Boltzmann constant ($1.381\ 10^{-23}$ J / K).
- T: cells effective temperature in Kelvin (°K).
- q: the electron charge ($q=1.6\ 10^{-19}$ C).

The fixed-point method consists of elaborating an iterative scheme, in this case, a convergent sequence toward a fixed point x of equation (3), this fixed point is the solution of the equation (1).

According to the notation taken at the fixed-point method, the equation (1) can be rewritten as:

$$y(I) = I - F(I) \quad (3)$$

The function F (I) means:

$$F(I) = I_{ph} - I_{01}\left(e^{\frac{V+R_sI}{n_1V_{tn}}} - 1\right) - I_{02}\left(e^{\frac{V+R_sI}{n_2V_{tn}}} - 1\right) - \frac{V+R_sI}{R_{sh}} \quad (4)$$

The current value I is in the range as: -0.5< I <2.5.

The proposed method is implemented using the well-known model of the grey solar cell parameters as in [5]. Table I presents these parameters.

We used data of Charles et al and Phang et al [5] [17] to evaluate different parameters for two solar cells, namely, grey solar cell (Table I).

TABLE. I. THE PARAMETERS OF THE SOLAR CELL "GREY" OBTAINED FROM [5], [17]

Parameter	Grey solar cell
V_{oc} (V)	0.524
R_s (Ω)	0.036740
R_{sh} (Ω)	55.485443
I_{01} (μA)	0.225974
I_{02}(μA)	0.749347
I_{ph} (A)	0.760781
V_{th} (mV)	26.479

C. Determination Diode Ideality Factor Optimal Value

Further to this, the diode ideality factors determination is giving according to the following steps:

To determine the optimal value of diode ideality factor, we use an iterative process and look for the corresponding meeting point I=F(I) for different curves of diode ideality factors values. This meeting point represents the optimal solution of the nonlinear equations (1).

The implementation process to determine the diode ideality factors we set the problem as:

- Find the point meeting I=F(I) for different values of n_1 and n_2.
- Using an iterative process, Fig. 3 shows the corresponding curve for each value of n_1 and n_2. The intersection I and F(I) around the point (0,0) is the solution of a particular diode ideality factors we are looking for.

a) Algorithm of diode ideality factor value determination using fixed point method:

- Define initialize conditions:

n_{01}, n_{02}, Δn

- Initialize parameters:

n_{01}=1 and n_{02}=1

- Start loop

While the meeting point is different to 0

Increment n_1 and n_2

Update n_1 and n_2

Compute y=I+F(I)

Repeat the loop until equal "0"

- Result: the final "n_1 and n_2" present the real value.

In this work, the fixed point method has been represented by a nested loop of complexity $O(n^2)$.

Fig. 2 shows the evolution of the function y according to different values of diode ideality factor.

The graph of f(I), shown in Fig. 3, crosses the graph of f(I)=I at different factors ideality values. The point (0,0) is the solution to equation (1).

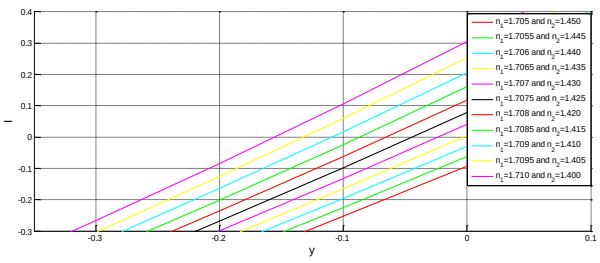

Fig. 2. Evolution of y (I)= I -f (I) for a Variable Diode Ideality Factor.

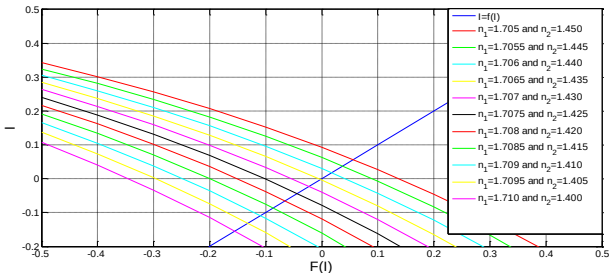

Fig. 3. Evolution of f (I) = I for a Various Diode Ideality Factor.

It requires extensive calculation and good approximations, which ensure the convergence of iterations. This method gives an explicit solution to the current-voltage equation (1) of the solar cell. Fig. 3 illustrates the different current-voltage characteristics of a gray solar cell for different diode ideality factors (small variations). We notify that the current depends on the diode ideality factor since the current increases gradually as the diode ideality factor decreases. The equation (1) solution converges to point I-F(I)=0 for two diode ideality factors of the double junction photovoltaic cell n_1= 1.7065 and n_2 = 1.435.

III. Results and Discussion

This section is devoted to discussing the obtained results compared with some related ones in the literature. This comparison concerns both performances of the solar cells and those of the solar modules.

A. Performance Comparison for Solar Cell

In order to evaluate the performance of the proposed method, the solar cell diode ideality factor extraction simulations and analysis were carried out for the different algorithms mentioned above as well as the fixed-point method. The comparisons operate on the parameter set values and absolute error.

For the algorithms named teaching-learning-based optimization, (TLBO) and simple teaching-learning-based optimization (STLBO) [19] were used to determine the unknown parameters in the nonlinear solar cell models since they are assigned for constrained mechanical design optimization problems. This technique is distinguished by fewer adjustable parameters. In [20], biogeography-based optimization (BBO) was used to find the optimal estimation parameters of both solar and fuel cells. BBO algorithm includes the mutation motivated from the differential evolution (DE) algorithm [21]; it gives solutions of high quality and has a fast convergence rate. In [22], the method applied is pattern Search (PS) that can divine a wide range of optimization problems. This technique minimizes the error associated with the estimated solar cell parameters. The technique applied in [13] uses a meta-heuristic approach for optimization, which is the particle swarm optimization (PSO) the algorithm that has a higher expectation to determine a global solution in comparison with deterministic ones.

The parameter values listed in Table II are represented in Fig. 4 to show the different results of different authors to solve the solar cell equation. The I-V experimental data has been

used by these algorithms for parameter extraction of the double diode model of equation (1).

Table II represents the calculated values compared to diode ideality factors obtained from different analytical and iterative methods.

According to Table II and Fig. 4, there is a correlation between the values of the diode ideality factors (n_1 and n_2) obtained from the different algorithms and those obtained from the fixed point method since the values calculated using the proposed method are close to those of the algorithms listed in the table.

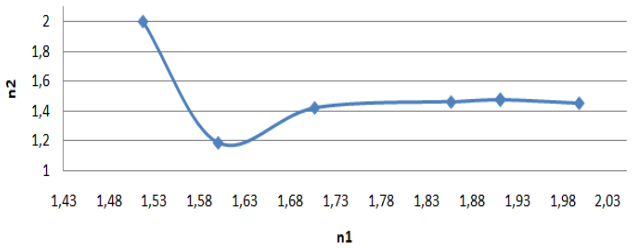

Fig. 4. Representation of Diode Ideality Factors (n_1, n_2) Values Extracted from different Algorithms.

TABLE. II. THE VALUES OF THE IDEALITY FACTORS OF THE DOUBLE-EXPONENTIAL SOLAR CELL EXTRACTED BY DIFFERENT ALGORITHMS

Algorithms / methods	**I_{ph} (A)**	**I_{01} (µA)**	**I_{02} (µA)**	**n_1**	**n_2**	**R_s (Ω)**	**R_{sh} (Ω)**	**RMSE**
Fixed point method	0.760781	0.225974	0.749347	1.70650	1.43500	0.036740	55.485443	1.7084 e^{-4}
TLBO [19]	0.76067	0.20289	0.29948	1.99809	1.47494	0.03646	55.8459	9.9507 e^{-4}
STLBO [19]	0.76078	0.22566	0.75217	1.45085	2.00000	0.03674	55.4920	9.8248e^{-4}
DE [20]	0.76079	0.36605	0.26320	1.91164	1.46500	0.03661	56.0213	1 e^{-3}
BBO [20]	0.75940	0.95830	0.14885	1.85714	1.42309	0.03673	58.4585	1.6 e^{-3}
PS [14]	0.7602	0.9889	0.0001	1.6000	1.1920	0.0320	81.3008	1.517 e^{-2}
PSO [13]	0.7623	0.4767	0.0100	1.5172	2.0000	0.0325	43.1034	1.66 e^{-3}
Rcr-IJADE [23]	0.760781	0.225974	0.749347	1.451017	2.00000	0.036740	55.485443	9.8602e^{-4}
CSO [24]	0.76078	0.22732	0.72785	1.45151	1.99769	0.036737	55.3813	9.8252e^{-4}
BMO [25]	0.76078	0.21110	0.87688	1.44533	1.99997	0.03682	55.8081	9.8262 e^{-4}
GOTLBO [26]	0.760752	0.800195	0.220462	1.999973	1.448974	0.036783	56.075304	9.83177 e^{-4}
ABSO [27]	0.76078	0.26713	0.38191	1.46512	1.98152	0.03657	54.6219	9.8344 e^{-4}
IGHS [28]	0.76079	0.97310	0.16791	1.92126	1.42814	0.03690	56.8368	9.8635 e^{-4}
BBO-M [20]	0.76083	0.59115	0.24523	2.00000	1.45798	0.03664	55.0494	9.8272 e^{-4}
GGHS [28]	0.76056	0.37014	0.13504	1.49638	1.92998	0.03562	62.7899	9.9097 e^{-4}
FPA [29]	0.760795	0.300088	0.166159	1.47477	2.0000	0.0363342	52.3475	7.7301 e^{-4}
HS [28]	0.76176	0.12545	0.25470	1.49439	1.49989	0.03545	46.82696	9.9510 e^{-4}
MPCOA [30]	0.76078	0.31259	0.04528	1.47844	1.78549	0.03635	54.2531	9.4457 e^{-4}
CARO [31]	0.76075	0.29315	0.09098	1.47338	1.77321	0.03641	54.3967	9.8260 e^{-4}
ABC [32]	0.7608	0.0407	0.2847	1.4495	1.4885	0.0364	53.7804	9.861 e^{-4}
DE [33]	0.76078	0.22599	0.75438	1.44972	1.99999	0.03674	55.4922	9.8246 e^{-4}
ABSO [33]	0.76078	0.22599	0.75439	1.44972	1.99999	0.03674	55.4922	9.8246 e^{-4}
ABCDE [33]	0.76078	0.22599	0.75437	1.44972	1.99998	0.03674	55.4921	9.8246 e^{-4}

The root means square error (RMSE) is used to quantify the difference between the calculated and the experimental currents. However, although the RMSE is smaller, the calculated values are more adequacies to the experimental I–V data of solar cells.

It is defined by:

$$\text{RMSE}=\sqrt{\frac{1}{N}\sum_{i=1}^{N}(I_{calculated}-I_{experimental})^2} \quad (5)$$

Where N is the number of experimental I-V data of a 57 mm diameter commercial silicon solar cell from the system under 1000 W/m^2 at 33°C [34], which is represented in Table IV.

The RMSE value provided by the fixed-point method is 1.7084e^{-4} as illustrated in Table II. It represents one of the low values.

To ensure an objective study of the fixed-point method and different algorithms in the next section, the calculated values and experimental I-V data of solar cell and the solar module were simulated.

Fig. 5 and 6 are a plot of the calculated value of current versus voltage and the power versus voltage. These figures show the effects of diode ideality factor variation (extracted from the different algorithm) on the I-V and P-V characteristics, the factor extracted from the fixed point method increased the voltage and the maximum power values.

a) Absolute Current Error (ACE): The absolute current error (ACE), which is defined as the absolute value of the difference between the calculated current and the measured current, is defined by equation 6. It used to show the performance and the robustness of the algorithm.

$$\text{ACE}=\left|I_{calculated,i}-I_{experimental,i}\right| \quad (6)$$

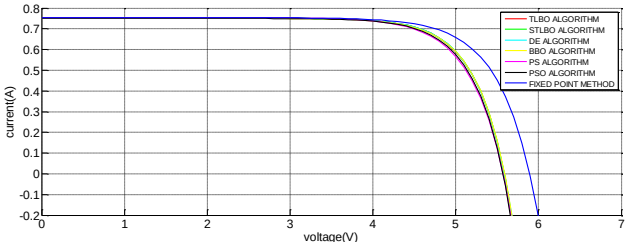

Fig. 5. Current-Voltage of Parameters Values Extracted from Several Algorithms.

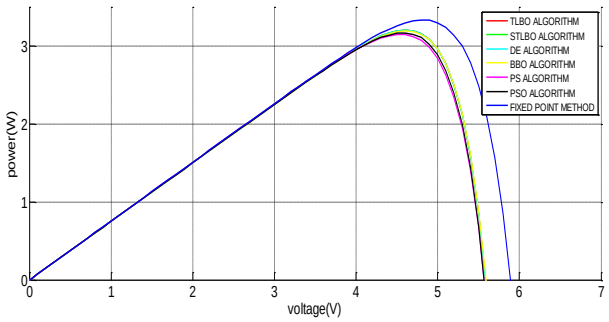

Fig. 6. Power-Voltage of Parameters Values Extracted from Several Algorithms.

The absolute current error sum is calculated in Table III.

Fig. 7 is a plot of the variation of absolute current error for a different method. At 0.3873 V, most of the algorithm achieves their maximum.

However, the fixed-point method and the BBO algorithm have almost the same absolute current error variation; its performance is chosen to be compared to the performance of the fixed-point method in Table IV.

Table IV summarizes the ACE value for fixed-point method and BBO algorithm based on the experimental I–V data. The fixed point RMSE value is 7, 77166e^{-6} and for BBO is 1, 10e$^{-5.}$

The experimental current value is different from the one of the current calculated in Table IV.

The simulated I-V characteristics of the fixed-point method as well as the BBO algorithm and their absolute current errors for each data point are shown in Fig. 8, 9 and 10, respectively.

The parameter simulation extracted from BBO algorithm for R.T.C France solar cell yields 3.5 W as a maximum power point and for the fixed point method, the peak of the power-voltage curve is 3.6 w.

The absolute current simulation indicate that the results of the fixed-point method coincide with the BBO algorithm data both in a double diode model, which means that the extracted parameters are very accurate.

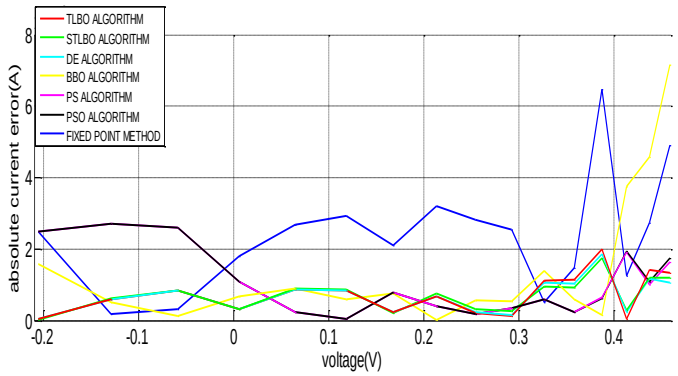

Fig. 7. Absolute Current Error of different Analytical and Iterative Methods.

TABLE. III. CALCULATED ABSOLUTE CURRENT ERROR FOR DOUBLE DIODE MODEL

Algorithms / methods	**ACE**
Fixed point method	3,84e^{-2}
TLBO [19]	1,31e^{-2}
STLBO [19]	1,25e^{-2}
DE [20]	1,22e^{-2}
BBO [20]	3,35e^{-2}
PS [22]	1,92e^{-2}
PSO [13]	1,71e^{-2}

TABLE. IV. SIMULATED OF THE EXPERIMENTAL I-V DATA OF R.T.C FRANCE SOLAR CELL [34] AND ABSOLUTE CURRENT ERROR USING FIXED POINT METHOD

Items (N)	Experimental data		Fixed point method		BBO algorithm	
	Voltage(V)	Current (A)	Calculated current(A)	ACE(A)	Calculated current(A)	ACE(A)
1	-0,2057	0,764	0,76649666	0,00249666	0,76243038	0,00156962
2	-0,1291	0,762	0,76182101	0,00017899	0,76148891	0,00051109
3	-0,0588	0,7605	0,76019100	0,00030900	0,76062446	0,00012446
4	0,0057	0,7605	0,75869387	0,00180613	0,75982953	0,00067047
5	0,0646	0,76	0,75732517	0,00267483	0,75909917	0,00090083
6	0,1185	0,759	0,75606716	0,00293284	0,75841572	0,00058428
7	0,1678	0,757	0,75490117	0,00209883	0,75774623	0,00074623
8	0,2132	0,757	0,75378517	0,00321483	0,75700885	8,8545E-06
9	0,2545	0,7555	0,75267857	0,00282143	0,75605193	0,00055193
10	0,2924	0,754	0,75146821	0,00253179	0,75454122	0,00054122
11	0,3269	0,7505	0,74999282	0,00050718	0,75189884	0,00139884
12	0,3585	0,7465	0,74796312	0,00146312	0,74710255	0,00060255
13	0,3873	0,7385	0,74498473	0,00148473	0,73864665	0,00014665
14	0,4137	0,728	0,74046200	0,00124620	0,72424173	0,00375827
15	0,4373	0,7065	0,73394175	0,00274417	0,70192341	0,00457659
16	0,459	0,6755	0,72458677	0,00490868	0,66834844	0,00715156

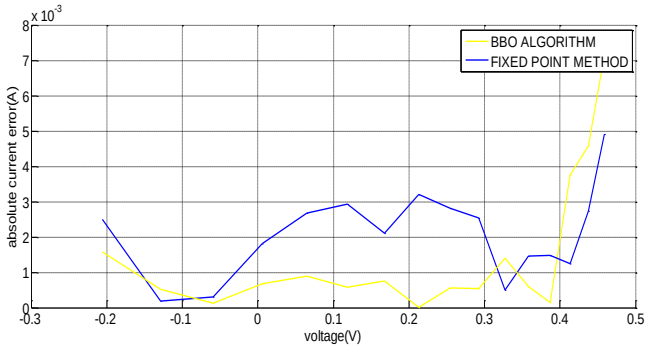

Fig. 8. Absolute Current Error Variation of Fixed Point Method and BBO Algorithm.

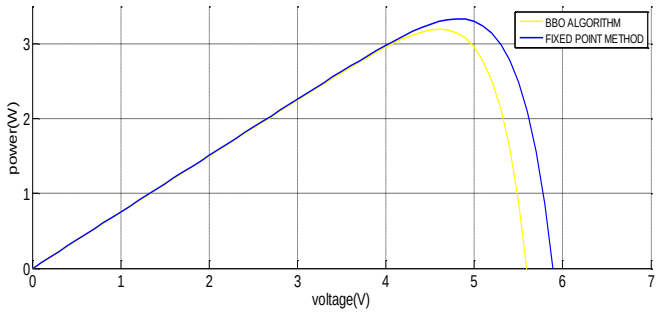

Fig. 9. Power-Voltage of Fixed Point Method and BBO Algorithm.

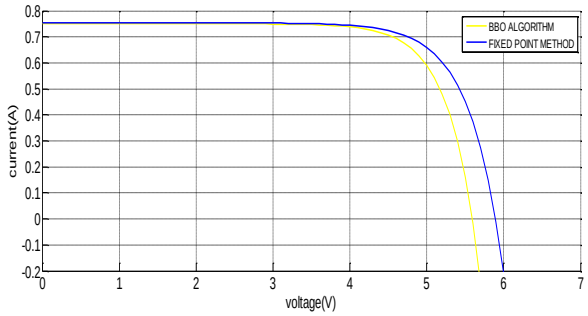

Fig. 10. Current-Voltage of Fixed Point Method and BBO Algorithm.

B. *Performance Comparison Results for Solar Module*

The fixed point method is evaluated using the reported parameter values extracted from FPA and experimental I–V data of solar module from mono-crystalline (SM55) [23]. The number of cells in series in this solar module is 36. The reported parameter values of the SM55 module are mentioned respectively in Tables V and VI.

It is essential to understand the effect of changing a solar cell temperature on the characteristic I = f (V) (Fig. 11 and 12), The current depends on the temperature since the current increases slightly as the temperature increases, but the temperature has a negative influence on the open-circuit voltage. When the temperature increases the open-circuit voltage decreases. Therefore the maximum power decreased.

TABLE. V. THE EXTRACTED PARAMETERS FOR MONO-CRYSTALLINE SM55 PV MODULE BY FPA AT DIFFERENT TEMPERATURE AND IRRADIATION OF 1000 W/M² (DOUBLE DIODE MODEL) [35]

Temperature (°C)	I_{ph} (A)	I_{01} (µA)	I_{02} (µA)	n_1	n_2	R_s (Ω)	R_{sh} (Ω)
25	3.450253	0.1302402	0.359717	1.373022	2.114513	0.3392569	442.917
40	3.467988	0.7258092	0.6681137	1.378014	3.896155	0.3389987	454.9449
60	3.49099	5.24174	20.85424	1.378047	3.560465	0.338981	470.6224

TABLE. VI. THE EXTRACTED PARAMETERS FOR MONO-CRYSTALLINE SM55 PV MODULE BY FPA AT DIFFERENT IRRADIATION AND TEMPERATURE 25°C (DOUBLE DIODE MODEL) [35]

Irradiation (W/m²)	I_{ph} (A)	I_{01} (µA)	I_{02} (µA)	n_1	n_2	R_s (Ω)	R_{sh} (Ω)
200	0.6905771	0.1398725	0.1419069	1.378175	3.45683	0.3390007	443.4634
400	1.380696	0.1392189	0.1215212	1.377924	2.297263	0.3386843	451.183
600	2.068947	0.1472423	0.1530210	1.382451	2.834106	0.3380305	480.1678
800	2.759354	0.1425452	0.6755132	1.379719	3.14591	0.3388229	469.336
1000	3.450253	0.1302402	0.359717	1.373022	2.114513	0.3392569	442.917

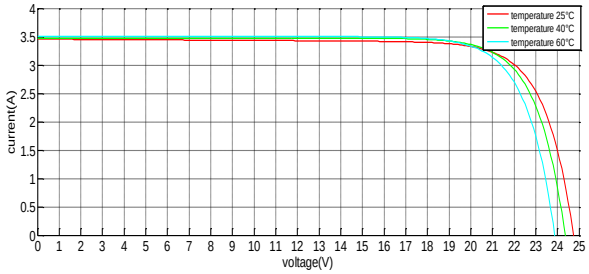

Fig. 11. Current-Voltage of SM55 PV Module for different Temperature.

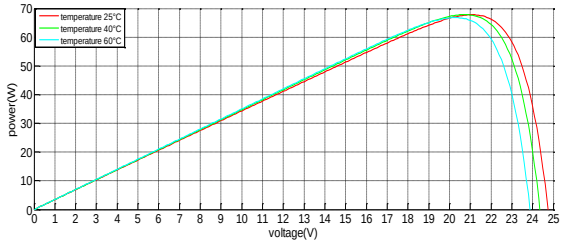

Fig. 12. Power-Voltage of SM55 PV Module for different Temperature.

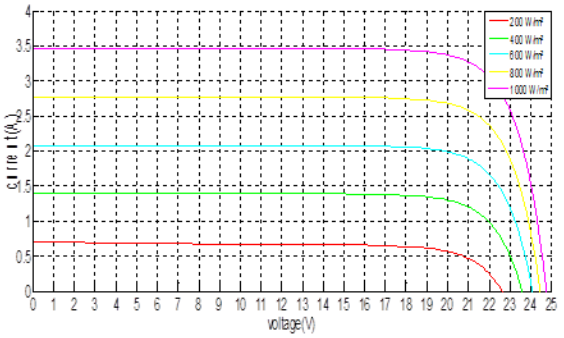

Fig. 13. Current-Voltage of SM55 PV Module for different Irradiation.

At a constant temperature (Fig. 13 and 14), it is found that the current undergoes a significant variation, but on the other hand, the tension varies slightly. Because the short circuit-current is a linear function of illumination while the open-circuit voltage is a logarithmic function.

In Fig. 15 and 16, the absolute current error in different radiation has the same variation as temperature. When the irradiation increases, the ACE increases, and decreases if the temperature increases.

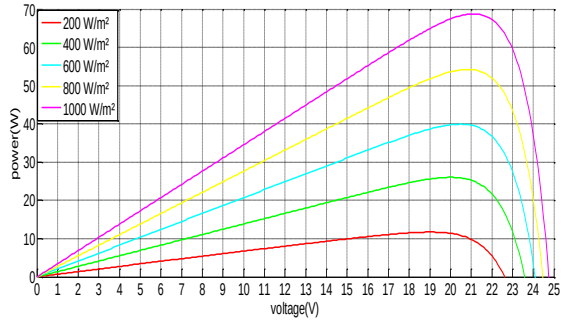

Fig. 14. Power-Voltage of SM55 PV Module for different Irradiation.

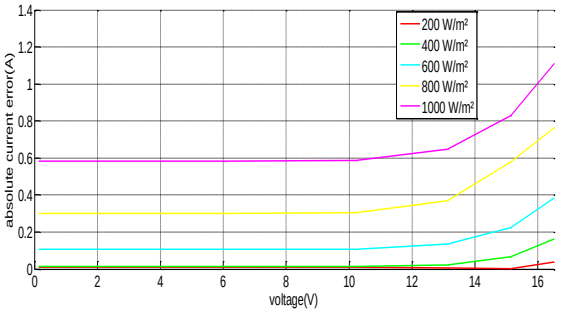

Fig. 15. Absolute Current Error of SM55 PV Module for different Irradiation.

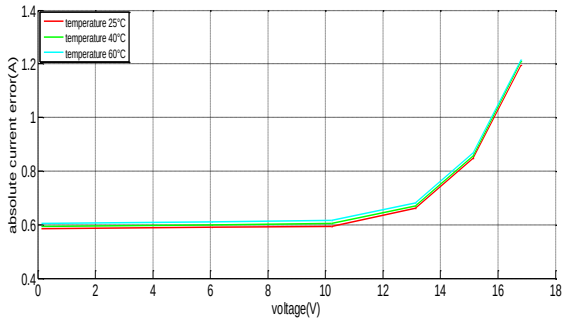

Fig. 16. Absolute Current Error of SM55 PV Module for different Temperature.

TABLE. VII. CALCULATED RMSE OF DOUBLE DIODE MODEL FOR DIFFERENT IRRADIATIONS

Irradiation (w/m²)	**RMSE**	**RMSE [5] (Lambert w-function)**
200	1.85 e^{-2}	2.45 e^{-2}
400	6.43 e^{-2}	2 e^{-2}
600	2.02 e^{-2}	2.15 e^{-2}
800	4.48 e^{-21}	4.24 e^{-2}
1000	7.8 e^{-2}	5.77 e^{-2}

TABLE. VIII. CALCULATED RMSE OF DOUBLE DIODE MODEL FOR DIFFERENT TEMPERATURE

Temperature (°C)	**RMSE**	**RMSE [5] (Lambert w-function)**
25	7.63 e^{-2}	5.77 e^{-2}
40	7.72 e^{-2}	2.71 e^{-2}
60	8.13 e^{-2}	2.09 e^{-2}

a) Comparison the RMSE calculated using the method above with the one calculated using Lambert w-function: The simulation results on the double diode model are shown in Tables VII and VIII along with comparable results reported from Lambert W-function.

The RMSE values obtained is smaller and it coincides to the RMSE calculated using Lambert w-function

IV. CONCLUSION

Most of the methods used to determine the diode ideality factor based on the solar cell simple diode model. As today there are several methods, it will be necessary to choose the appropriate methods in which the least approximations are made. The double diode model of characteristic I-V is the most appropriate model to understand the different physical phenomena occurring in each device region and to simulate adequately the operation of solar cells.

This paper presents a fixed point method based on double diode model of solar cells to extract the diode ideality factor values that solve nonlinear equations. The diode ideality factor values were found is close to extracted value by different algorithms.

We deduce from equation (1) and for a fixed temperature, the diode ideality factor decreases as the current increases. This factor varies depending on the semiconductor and the diode dimensions.

Moreover, the proposed methods allowed determining an approximate curve which will facilitate the extraction of the diode ideality factor (n_1 and n_2) appropriate values.

The proposed method is compared to other similar algorithms in the literature such as BBO, PSO, PS, DE, TLBO, and STLBO. The algorithms and method efficiency has been evaluated in terms of accuracy.

The comparison of the fixed point method to other algorithms proved that there is a correlation between the optimal value of the ideality factors of the diode n_1 and n_2 defined by the fixed point method and those obtained from other techniques; so this method can be applied to a junction and multiple junctions.

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The Impact of Flyweight and Proxy Design Patterns on Software Efficiency: An Empirical Evaluation

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***Abstract*—In this era of technology, delivering quality software has become a crucial requirement for the developers. Quality software is able to help an organization to success and gain a competitive edge in the market. There are numerous quality attributes introduced by various quality models. Various researches and studies prove that the quality of the object-oriented software can be improved by using design patterns. The main purpose of this research is to identify the relationships between the design patterns and software efficiency quality attribute. This research is focused on the impact of Flyweight and Proxy Design Patterns on the efficiency of software. An example scenario is used to empirically evaluate the effectiveness of applied design refinements on efficiency of a system. The techniques to measure software efficiency and the results obtained for each solution are elaborated in detail. At the end of this research, comparative analysis is provided to show the relative impact of each selected design pattern on software efficiency.**

***Keywords*—Software efficiency; design patterns; flyweight design pattern; proxy design pattern; measuring software efficiency; empirical evaluation of software**

I. Introduction

Efficiency is an essential quality factor that needs to be considered by every software engineer while designing a software program. A highly efficient software can give its users a more pleasant experience when interacting with the software by being more responsive to the user's actions and commands. To design and develop a highly efficient software, designers will have to minimize the system resources used by the software to accomplish the tasks. Increasing the efficiency of the software through the likes of lowering the process time and memory used by the software will make the users feel that the software is more responsive as time used to process their input and provide an output will be lower. The minimal usage of memory will also decrease the time used to search for data, further lowering the processing time.

Due to the competitive nature of software development, developers would need to find ways to satisfy the users' needs. One of the problems of measuring software quality is that it is often intangible and abstract. Therefore, to combat the problem that developers usually face, Jim McCall and several other software engineers have presented their models to ensure quality of developed software using available industry standards.

There are three perspectives of quality attributes in Jim McCall's model, namely Product Revision, Product Transition, and Product Operations. Product revision is the ability or enhancement of the ability for the software to change in accordance to user needs. Product transition on the other hand, is the ability for the software to adapt itself to changing environments. Finally, product operation, which is the topic of discussion of this research, is defined by the ability of the software to operate in accordance to the user demands and without defects [1].

Efficiency is "the state or quality of being efficient", which is the ability of a system or machine on "achieving maximum productivity with minimum wasted effort or expense" or the ability of a person "working in a well-organised and competent way" [2]. However, in the context of software engineering, efficiency is the capability of a software application to fully utilize the amount of resources that are required to perform a task, the resources are inclusive of CPU time, storage, transmission channels and others [3] [4].

As this research is aimed to evaluate the efficiency of software systems, authors are interested in "the ability of a system on achieving maximum productivity with minimum wasted effort or expenses", which in a simpler form is processing most input into output with least amount of resources. Since resource distribution to run software systems are on average the same, more efficient software can usually finish the same task in less amount of time.

II. Literature Review

A. Importance of Efficiency in Contemporary Software Systems

With the development of increasingly advanced hardware, most software, even inefficient, do not need to take full advantage of hardware resources except for a few types, such as games. Due to the abundance of hardware resources, software development typically has low efficiency standards, since the development of an efficient software is more expensive. Due to the higher cost of developing a more efficient software, the end product would also end up costing more. Moreover because of the fact that the end users prefer cheaper products and would usually not notice the subtle difference in performance, commercial software would choose to enhance other aspects of the software rather than enhancing the efficiency [5].

Efficiency is often traded off with other quality attributes as efficiency always comes last in terms of urgency and priority [6]. However, for some real-time systems such a banking system, efficiency is a critical factor in order for the system to be proven useful and successful. Even though the weakness of software efficiency is compensated by the advancement of hardware, efficiency is still pivotal as many users of software are using various specifications of laptops, tablets and smartphones. On the other hand, battery life is an important factor to be considered for mobile devices. If a mobile device is constantly running inefficient software, it will occupy more resources and the battery will be consumed faster.

A case study by [7], depicts the fact that complex systems such as banking systems that require real time interaction between multiple actors are difficult to implement as issues such as efficiency and reliability arises in the process of designing and actually producing the system. Furthermore, introduction of the system over a large geographical area (inclusive of rural areas) requires even more attention towards efficiency as data has to be transmitted, received, and synced among all nodes within the network in real time. The same could be seen in Healthcare Systems which poses emphasis on efficiency as the equipment which are connected using Internet of Things (IoT) have to provide real-time response for notification purposes when the monitored patient's condition is near or in emergency level [8] and serious implications could happen when the system fails to extend immediate feedback to the target audience (in this case, the nurses and the doctors) for assistance.

Efficiency is becoming more important in software applications that uses emergent technologies as it emphasize on using fewer resources to achieve better results, saving computational time and storage. The importance of efficiency can be seen through telecommunication software applications such as Skype, WhatsApp or Facebook Messenger which provides video or voice calling services through wireless networks. In the context of Skype, a study that was done by [9] have shown that the video quality of Skype calls is greatly affected by the efficiency of Skype's transmission and encoding algorithms as well as utilizing the bandwidth resource provided by the targeted machine itself. Similarly, within the healthcare sector, through integration of IoT, surgeons are able to perform telesurgery on patients without having to be physically present at the operation theatre [10]. In these cases, efficiency of the software application is extremely crucial as defective or inefficient software could potentially put the patient's life to risk, hence the software application must perform at maximum efficiency to ensure there is zero to none disruption. Content management system (CMS) which is a type of data driven system is used to perform CRUD (create, remove, update, delete) functionalities on text data and this stored data is then used for big data analytics [11]. Due to the large amount of data being stored in the database, the software has to utilize the computing power by optimizing insert and retrieval codes to ensure the performance of the system.

In a typical enterprise environment, development of software applications is usually done on cloud where services are delivered to clients or end-users through powerful virtualized data servers that are equipped with high bandwidth and low latency network speed that are kept in data-centers that are owned by external parties (the cloud service providers such as Microsoft Azure, Amazon Simple Storage Service et cetera.) [12]. Cloud computing is considered as the integration of both Grid Computing and Cluster Computing paradigms. Cloud computing architecture allows the software system to be easily expandable and scalable due to the nature of the services provided [13]. However, efficiency is one of the main reasons why most enterprises begin to shift their services to be hosted through the cloud instead of having the servers hosted and managed manually within their company's premises. Efficiency could be achieved in cloud computing paradigm through shared resource pooling which improve data storage and processing power, for example the service providers dynamically assign computing resources to multiple consumers only when needed, hence maximum utilization of computing resources could be achieved [14]. Also, the amount of computational power or storage could be increased or decreased at any point of time based on the amount of resources that will be needed by the software application; hence it does not waste computing resources and at the same time allows consumers to save cost. Due to the flexibility, consumers can ensure that optimum efficiency is reached in order to provide end-users with a system that runs with high performance. Through cloud computing architecture, consumers do not have to worry with concerns on hardware issues and can pay full focus in development of software.

B. Methods to Improve Software Efficiency

1) Code optimization: In order to achieve higher efficiency in software applications, the developers of the system should be able to fully grasp and understand how codes function at an operating system level and optimize the codes to enhance computing resource utilization as area of slowness could only be identified through knowledge and experience in dealing with system related matters. For instance, declaring cached reference of objects that is frequently used as a local variable could greatly help in reducing the processing power needed to complete a task [15]. The diagram represented by Fig. 1 below shows the actual implementation of cached memory.

In Fig. 1, the code snippet on the left is the initial implementation of the code without using cached memory. The difference in two implementations is only a line of code, however it can make a huge difference when the computer interprets the code. The code on left have to retrieve the draw method every single time the loop is executed, however the code on the right retrieves the draw method once, and for each loop execution the reference to the retrieved method is called. Various modifications such as avoiding recursion, managing threads etc. could also help in enhancing efficiency of a software application [16].

```
for i in xrange(1000):
    my_mesh.draw()
```

```
draw_method = my_mesh.draw
for i in xrange(1000):
    draw_method()
```

Fig. 1. Code Snippets Showing the Variation in Efficiency.

2) Parallel programming: Parallel programming is the method of programming which utilize threads where each thread could process a single line of command, however many threads could be created and kept alive concurrently. In the current real-world scenario, industries are paying more focus on hardware components rather than software quality, hence stronger processing chips are being researched on and produced over the years whereas the efficiency of a software is still neglected and there is no major improvement in terms of efficiently utilizing the computing power which is being provided by the chips [17]. However, in systems which are heavily reliant on efficiency, parallel programming would be among the most suitable to be implemented within the actual source code.

3) Design patterns: Design patterns are tested and reusable solutions to reoccurring problems. Some of the most commonly used software design patterns are the twenty-three object-oriented patterns proposed by the Gang of Four (GoF), consisting Erich Gamma, Richard Helm, Ralph Johnson, and John Vlissides, in their book "Design Patterns: Elements of Reusable Object-Oriented Software", published in 1994 [18]. Design patterns could be commonly seen within the context of object-oriented programming where coupling and coherence plays a very important role in determining the quality of a software. Design patterns are classified into three categories, creational addressing the process of object creation; structural addressing composition of objects and classes; behavioral addressing how classes and object interact and distribute responsibility [18]. Through the usage of design patterns, a common structure of code implementation can be applied to solve certain type of issues. As design patterns are commonly used, recognized and practiced by experienced object-oriented developers, the solutions can be categorized to be the best possible solution in specific situations. Since they are commonly used by developers, the solutions are practically stable in nature. Most of the time in the real-world environment, design patterns are also the commonly used as a base for most software development projects, this help saves time as reoccurring problems could be solved immediately through implementation of design patterns without the need of rethinking code structure and design for constantly emerging problems. As exploring design patters for improvement in efficiency is the core objective of this research, subsequent sections provide details on how it can impact software efficiency.

C. Impact of Design Patterns on Software Efficiency

Design patterns could help in breaking down tight coupling between classes and objects and with such, the structure of an application can be broken down into few separated parts which is typically implemented through the MVC (model, view and controller) architecture. Efficiency of a software could be improved by implementing heavy loading (functions that require a large amount of processing power) to be done at server-side machines with higher computational power and allowing clients to access the Web APIs service to invoke the functions and features [19]. Within the MVC architecture, the Decorator pattern can be used in controller, the Strategy pattern between the controller and view and the Observer pattern in order to notify the view when the model is changed, whereas Factory pattern can be used for creation of multiple views or controllers.

Design patterns could also help in reducing the computing power consumed by an application but instantiating lesser objects and instead of creating new objects, similar objects are shared in usage. For example, the Flyweight design pattern allow objects to be shared. Whereas the Proxy design pattern can improve the efficiency of an application by avoiding duplication of object especially for objects that is very large in size. For example, in a typical web application environment, end users usually make requests to the server multiple times, instead of responding multiple times, the proxy pattern will check if the existing object exists and try to return the local reference if there is an existing object.

Some of the existing researches also suggest that the design patterns Factory, State, and Proxy can improve the performance of a software system by caching or skipping repetitive procedures [20, 21, 22, 23, 24, 25, 26]. In one of the tests conducted by Erik Jansson, it was shown that flyweight has noticeably improved the memory usage of the software [27].

Following is a brief description of the Flyweight and Proxy design patterns, which are used in this research for studying the impact on software efficiency:

1) Flyweight design pattern: The Flyweight design pattern as defined by GoF [18] is "using sharing to support large numbers of fine-grained objects efficiently". In other words, flyweight is a pattern which aims to reduce the number of objects that are created, and instead of creating a large number of objects with tiny differences in attributes the Flyweight will use the shared pool of objects with intrinsic state and extrinsic state properties [28]. The intrinsic state is the predefined states for the object which is constant and unchangeable whereas the extrinsic state is the attribute which is determined during run time. Fig. 2 below shows the general structure for Flyweight implementation.

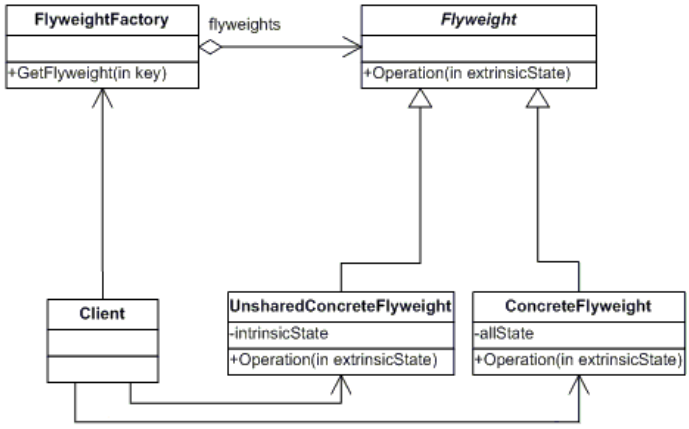

Fig. 2. Flyweight Generic Design.

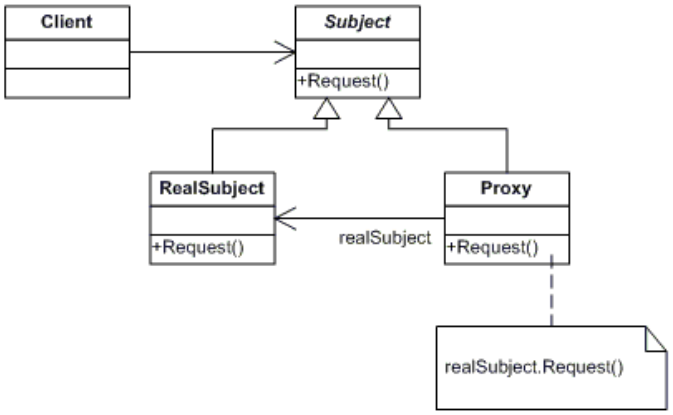

Fig. 3. Proxy Generic Deisgn.

2) Proxy design pattern: The Proxy design pattern as defined by GoF [18], is "providing a surrogate or placeholder for another object to control access to it". Proxy is categorized into four main types, which are the remote proxy, virtual proxy, protection proxy and smart proxy respectively. Remote proxy is used for the purpose of accessing remote services by processing on the request that was sent by the client; Virtual proxy is for delaying the sending of the actual until the moment where the data is required; Protection proxy is to act as a layer of protection when accessing data; Smart proxy is to check the caching of objects. As shown in Fig. 3 above, the Proxy design pattern consists of four main components, the Client which send requests; the Subject (interface) which handles request made by the Client; the Real Subject which is the actual object or data; the Proxy which is a pointer or reference to the actual data or object. The Proxy acts a checker or a control which identifies if similar request is previously sent from the Client, if the result to the request is found within the local context of the Proxy, then the Proxy will redirect the request to the local reference of the result instead of accessing the Real Subject to request for the result again. In cases where the Real Subject is heavyweight, through the implementation of proxy design pattern, greater efficiency could be achieved.

D. System Attributes related to Efficiency

As efficiency is a broad term, there exists many ways in which one can measure a system's efficiency. As proposed by [29], there are a few sub-factors in a system which are related to efficiency. The sub-factors include:

- Time Behavior–The response time, throughput, and capacity to perform of a system.
- Resource Behavior–How much resource is used by the system while performing its tasks. The resources can be random access memory (RAM), read-only memory (ROM) as well as the utilization of Input and Output device.
- Reply Time–The time passed between which an inquiry or demand is given to a system and the beginning of the system's response to the inquiry or demand.
- Processing speed–The amount of time used by a system to complete a task or the actual time spent by the user on the system to generate a result.
- Execution Efficiency–The run time performance of a component in the system.
- Robustness–The ability of a component in the system to execute tasks correctly when given incorrect inputs or while under stressful environmental conditions to give desired results.

With higher efficiency, less hardware resources and more importantly, less time will be consumed, and accomplishing more tasks deemed very important by the user under a given amount of time. Therefore, in order to measure the efficiency of a system, these factors should be considered.

III. Design and Implementation of Simpler and Refined Solutions

To measure the impact of design refinements on system efficiency, a simple imitation of an online shooter game is designed and implemented. Initially a simpler solution is implemented without applying any design refinements. Then the same design is improved by applying appropriate design patterns and the solutions is re-implemented. Finally efficiency of simpler legacy solution as well as the refined design pattern based solutions are calculated by measuring the execution time and memory usage. Comparison of the solutions highlight the impact and effectiveness of the design patterns used and help in identifying the design refinements that should be used to make a software system efficient.

Scenario: In an online shooter game, there are two teams consisting of defenders and attackers. 200 players will be playing in a single map and they can either choose to be an attacker or defender. These players can also choose their desired weapons. Once players have chosen their weapons, the attackers will spawn at a location and the defenders will spawn another. For imitation purpose, the 200 players will randomly choose classes and we assume that the likelihood of them picking each of the weapons will be the same. The attackers are assigned the task to attack the objective while the defenders are assigned to defend it.

Following represents the design of a simpler solution:

As shown in Fig. 4, the basic solution contains four (4) classes. The Players are separated into Attackers and Defenders. The OnlineShooter class (Fig. 5) will then spawn the Attacker and Defender Players. In the OnlineShooter class, there are 2 arrays which are playerTeam, containing the teams the players can join, and Weapon, which is the weapon that the players can pick. For each player, the player will be generated by placing them into a random team with a random weapon selected using the Java Random utility. Once the player is loaded, they will be spawned.

The Player interface (Fig. 6) contains methods that will be implemented in the Attacker and Defender class which are assignWeapon(String weapon), for assigning the randomly chosen weapon to the players, spawn(), which spawns the players, and loadModel() which will load the player models.

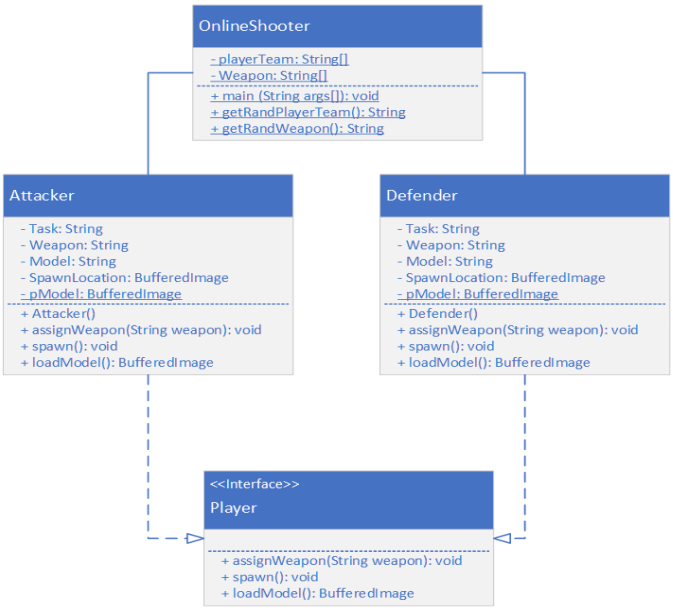

Fig. 4. UML Class Diagram for Simpler Solution.

```
package dpatproj.basic;
import java.util.Random;
public class DPATProjBasic {
    private static String[] playerTeam = {"Attacker", "Defender"};
    private static String[] Weapon = {"Bow","Sword","Axe","Shield",
                "Dagger","Sabre","Spear","Club","Hammer","Glaive"};

    public static void main(String[] args) {
        for(int i=0;i<200;i++){
            Player p = null;
            String PlayerTeam = getRandPlayerTeam();
            if (PlayerTeam == "Attacker"){
                p = new Attacker();
                System.out.println("Attacker Created");
            }
            else if (PlayerTeam == "Defender"){
                p = new Defender();
                System.out.println("Defender Created");
            }
            else{
                System.out.println("No such player");
            }
            if (p != null){
                p.assignWeapon(getRandWeapon());

                p.spawn();
            }
        }
    }
    public static String getRandPlayerTeam(){
        Random r = new Random();
        int randInt = r.nextInt(playerTeam.length);
        return playerTeam[randInt];
    }
    public static String getRandWeapon(){
        Random r = new Random();
        int randInt = r.nextInt(Weapon.length);
        return Weapon[randInt];
    }

}
```

Fig. 5. Online Shooter Class.

```
package dpatproj.basic;

import java.awt.image.BufferedImage;

public interface Player {
    public void assignWeapon(String weapon);
    public void spawn();
    public BufferedImage loadModel();
}
```

Fig. 6. Player Interface.

```
package dpatproj.basic;
import java.awt.image.BufferedImage;
import java.io.File;
import javax.imageio.ImageIO;
public class Attacker implements Player{
    private final String Task;
    private final String Model;
    private String Weapon;
    private BufferedImage SpawnLocation = null;
    private static BufferedImage pModel;

    Attacker(){
        Task = "ATTACK THE OBJECTIVE";
        Model = "Example.png";
        try{
            SpawnLocation = ImageIO.read(new File(Model));
        }catch (Exception e){}
    }

    public void assignWeapon(String weapon){
        this.Weapon=weapon;
    }

    public void spawn(){
        pModel = loadModel();
        System.out.println("Attacker with weapon " + Weapon +
        " spawned |" + " Task is " + Task);
    }
    public BufferedImage loadModel(){
        System.out.println("Loading Model " + Model + "...");
        BufferedImage img = null;
        try{
            img = ImageIO.read(new File(Model));
        }catch (Exception e){
            System.out.println("Player model not found!");
        }
        System.out.println("Model "+ Model + " loaded");
        return img;
    }
}
```

Fig. 7. Attacker Class.

As Attacker and Defender classes are similar, only the Attacker class is shown in Fig. 7 above. In both Attacker and Defender class, the task, file location of the player model, and the weapon assigned are stored as Strings, while the spawn location and actual player models are stored as buffered images to simulate the actual process of loading the players, which needs a considerable amount of time and memory.

A. First Design Refinement using Flyweight Design Pattern

In above design and implementation, there is a problem with the system needing to create a completely new Player object for every single player loaded, even though there are only slight differences between the different Player objects. For each Attacker or Defender, the Task, Model, and Spawn Location are the same, with only their weapon being different.

This creates a situation where the system needs to create about 99 player objects for each type of player which can be avoided.

To solve this issue, Flyweight design pattern is implemented. By using Flyweight, each Player object will only have to be instantiated once, which can then be reused repeatedly, only needing to reassign their weapons each time instead of reassigning everything. The refined UML Class Diagram (Fig. 8) is depicted below.

As can be seen from Fig. 8 below, most of the classes remained same as the basic implementation, except that a PlayerFactory class is added, which the OnlineShooter class will use for the generation of Players. The implementation of the Attacker and Defender classes as well as the Player interface is the same. The DPATProjFlyweight in the implementation however, has a minor change, which is the generation of Player object, instead of directly making a new Player, the player is gotten from the PlayerFactory class.

The PlayerFactory class, as shown in Fig. 10, is a new class that was not implemented in the simpler solution of the scenario. The class contains a HashMap, which will be used as a key that is associated with created objects. When the getPlayer() method is called, the system will first check if the player type is already created by searching for the associated key. Then return the player object if it is already created, not needing to recreate a new object. If the associated key cannot be found, only then the system will create a new object and store it with its associated key before returning it.

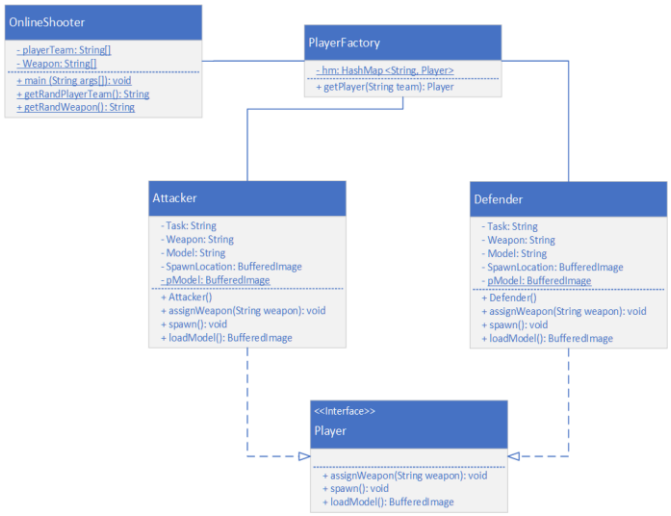

Fig. 8. UML Class Diagram for Flyweight Pattern based Refinement

```
public static void main(String[] args) {
    for(int i=0;i<200;i++)
    {
        Player p = PlayerFactory.getPlayer(getRandPlayerTeam());

        p.assignWeapon(getRandWeapon());

        p.spawn();
    }
}
```

Fig. 9. Online Shooter Class tweak

```
package dpatproj.flyweight;

import java.util.HashMap;

public class PlayerFactory {

    private static HashMap <String, Player> hm = new
    HashMap<String, Player>();

    public static Player getPlayer(String team)
    {
        Player p = null;

        if (hm.containsKey(team))
                p = hm.get(team);
        else
        {
            switch(team)
            {
            case "Attacker":
                System.out.println("Attacker Created");
                p = new Attacker();
                break;
            case "Defender":
                System.out.println("Defender Created");
                p = new Defender();
                break;
            default :
                System.out.println("No Such Player Type");
            }

            hm.put(team, p);
        }
        return p;
    }
}
```

Fig. 10. Player Factory Class.

B. Second Design Refinement using Proxy Design Pattern

There is still an issue in the refined solution, whereby before each player is spawned; their player models need to be loaded from a specific file. In this case, spawning 200 players would mean that the system would have to repeatedly read the player model from a remote file for 200 times, which 99 times can be avoided for each player type (as in Fig. 9).

To resolve this issue, Proxy design pattern is implemented alongside Flyweight, where each player type's model file would only have to be accessed and read once, and then the system will store the remote file's information as an object, which can then be reused repeatedly without needing to access the remote file again. Fig. 11 shows the UML class diagram designed for the implementation with Proxy design pattern.

In the refined UML class diagram (Fig. 11) depicted above, no changes are made to the already existing classes except for a few variables in the Attacker and Defender classes. However, two interfaces AttackerModel and DefenderModel, which are the player models for each of their respective player types, are added. Proxy player model classes ProxyAtkM and

ProxyDefM as well as real player model classes RealAtkM and RealDefM are shown for their respective player types. As in the first refinement, classes that are unchanged are not shown here, that include OnlineShooter (renamed to DPATProjFProxy), PlayerFactory, and the Player interface. There are slight changes to the Attacker and Defender classes. The String Model variables are changed to a type of their respective model classes and the loadModel() method is replaced by the getModel() method, which gets the player model from their respective classes as a BufferedImage as shown in Fig. 12 below.

The AttackerModel and DefenderModel interfaces in Fig. 13 and Fig. 14 contain a getModel() method, which is used for the Attacker and Defender classes to get player model.

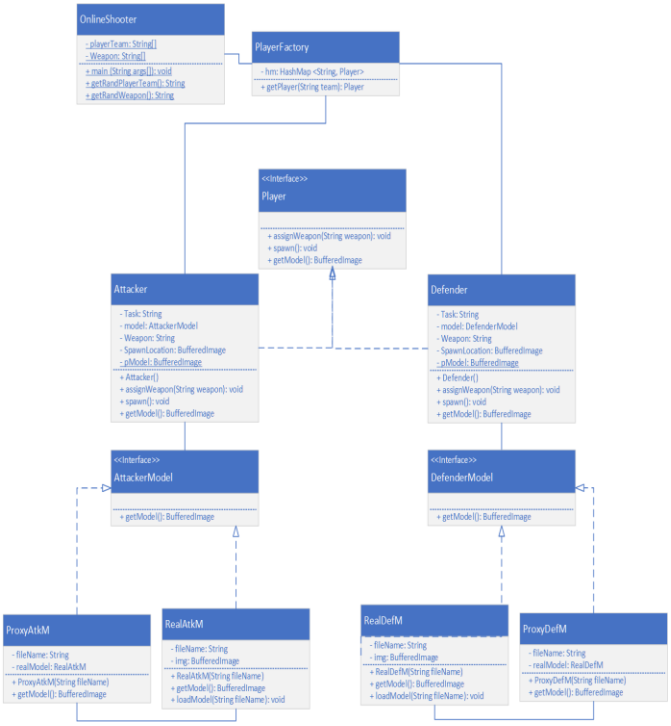

Fig. 11. UML Class Diagram for Proxy Pattern based Refinement.

```
private final String Task;
AttackerModel model;
private String Weapon;
private BufferedImage SpawnLocation;
private static BufferedImage pModel;

public BufferedImage getModel(){
    BufferedImage pImg = model.getModel();
    return pImg;
}
private final String Task;
DefenderModel model;
private String Weapon;
private BufferedImage SpawnLocation;
private static BufferedImage pModel;

public BufferedImage getModel(){
    BufferedImage pImg = model.getModel();
    return pImg;
}
```

Fig. 12. Player getModel().

```
public interface AttackerModel {
    public BufferedImage getModel();
}
```

Fig. 13. AttackerModel interface.

```
public interface DefenderModel {
    public BufferedImage getModel();
}
```

Fig. 14. DefenderModel Interface.

The ProxyAtkM and ProxyDefM classes in Fig. 15 and Fig. 16 are the proxy classes for the player models. There are String variables for storing the file name of the player model and RealAtkM and RealDefM type classes which is used to refer to the real model classes. When the getModel() method is called, it will first check if the real model classes are instantiated, and get the player model from the real model class and return it.

```
package dpatproj.fproxy;

import java.awt.image.BufferedImage;

public class ProxyAtkM implements AttackerModel{
    private String fileName;
    private RealAtkM realModel;

    ProxyAtkM(String fileName){
        this.fileName = fileName;
    }

    public BufferedImage getModel(){
        if (realModel == null){
            realModel = new RealAtkM(fileName);
        }
        return realModel.getModel();
    }
}
```

Fig. 15. ProxyAtkM Class.

```
package dpatproj.fproxy;

import java.awt.image.BufferedImage;

public class ProxyDefM implements DefenderModel{
    private String fileName;
    private RealDefM realModel;

    ProxyDefM(String fileName){
        this.fileName = fileName;
    }

    public BufferedImage getModel(){
        if (realModel == null){
            realModel = new RealDefM(fileName);
        }
        return realModel.getModel();
    }
}
```

Fig. 16. ProxyDefM Class.

The RealAtkM and RealDefM classes in Fig. 17 and Fig. 18 are responsible for loading and storing the player model from the remote file. Similar to the proxy classes, there is a String variable in each of the real model classes to store the file name of the model. The BufferedImage is first instantiated as null but when the class is first instantiated, the model will be loaded into the BufferedImage. When the getModel is called by the proxy classes every next time, the BufferedImage will be returned without needing to be loaded again.

```
package dpatproj.fproxy;

import java.awt.image.BufferedImage;
import java.io.File;
import javax.imageio.ImageIO;

public class RealAtkM implements AttackerModel{
    private String fileName;
    BufferedImage img = null;

    RealAtkM(String fileName){
        this.fileName = fileName;
        loadModel(fileName);
    }

    public BufferedImage getModel(){
        System.out.println("Model " + fileName + " Loaded");
        return img;
    }

    public void loadModel(String fileName){
        System.out.println("Loading Model " + fileName + "...");
        try{
            img = ImageIO.read(new File(fileName));
        }catch (Exception e){
            System.out.println("Player model not found!");
        }
    }
}
```

Fig. 17. RealAtkM Class.

```
package dpatproj.fproxy;

import java.awt.image.BufferedImage;
import java.io.File;
import javax.imageio.ImageIO;

public class RealDefM implements DefenderModel{
    private String fileName;
    BufferedImage img = null;

    RealDefM(String fileName){
        this.fileName = fileName;
        loadModel(fileName);
    }

    public BufferedImage getModel(){
        System.out.println("Model " + fileName + " Loaded");
        return img;
    }

    public void loadModel(String fileName){
        System.out.println("Loading Model " + fileName + "...");
        try{
            img = ImageIO.read(new File(fileName));
        }catch (Exception e){
            System.out.println("Player model not found!");
        }
    }
}
```

Fig. 18. RealDefM Class.

IV. Empirical Evaluation and Analysis of Results

Efficiency of a system can be calculated by measuring its execution time and its memory usage when executing tasks. The efficiency of a system is inversely proportional to both memory usage and execution time. Therefore, in order for a system to be considered as efficient, its memory usage as well as execution time needs to be as low as possible. In order to show the impact of design patterns on system's efficiency, the memory usage will be measured in Mega Bytes (MB) and its execution time will be measured in Seconds.

To measure these attributes of the system, the above designs are implemented in Java programming language using NetBeans IDE. NetBeans is chosen as it has an internal profiler which automatically tracks the project's memory usage, CPU usage and Garbage Collection, etc. To obtain system's memory usage, one would only need to run the project in the profiler's telemetry tab, and the memory usage at each stage of the project's execution will be shown in a graphical form. For each execution of a project, NetBeans' internal output console will also display the project's completion time after it has finished executing the project. The completion time can then be directly translated to the execution time of the system. To simulate large amount of data being processed by a real system, BufferedImage (a Java library) is used. The large file size of an image, when loaded into the system using BufferedImage, can simulate a large object in a real system. Without the existence of a large object, the execution time and memory usage of the implementation will be too low to have a noticeable difference.

Each variant of differently designed implementation was run multiple times using NetBean's built-in profiler to obtain the memory usage and execution time so that the time needed to start the profiler is not calculated into the execution time. Following are the results for each of the three variant implementations discussed above:

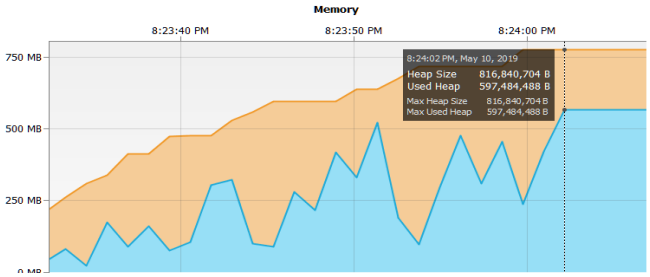

Fig. 19. Memory usage by Simpler Legacy Solution.

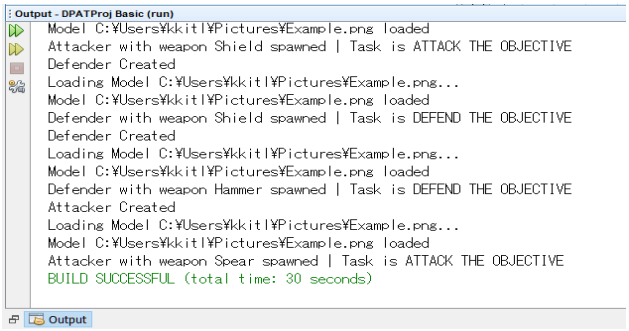

Fig. 20. Execution Time Taken by Simpler Legacy Solution.

The results for the simpler implementation are shown in Fig. 19 and Fig. 20 above. The memory needed to complete running the system was 817MB and the execution time was 30 seconds. As one would expect, the memory and time would increase proportionally to the number of players generated as well as the file size of the Buffered Image.

Fig. 21 and Fig. 22 shows the results for refined implementation with Flyweight pattern. Here the memory needed to complete the execution of the project was 648MB, which is significantly lower than the simpler solution, while the execution time was 15 seconds, which is half of what the simpler implementation needed.

Finally, the results of running the second refinement using both Flyweight and Proxy design pattern are shown in Fig. 23 and Fig. 24. The memory usage is even lower than the first refinement, only needing 129MB. The execution time was surprising reduced to less than 1 second.

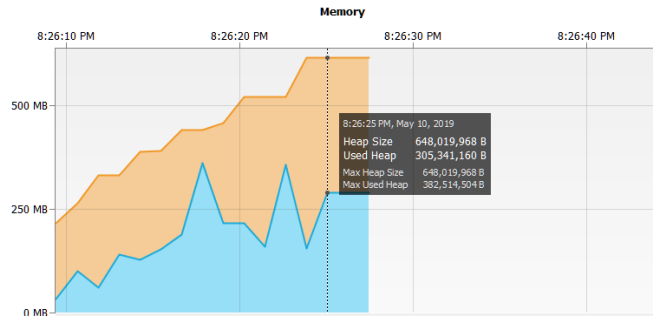

Fig. 21. Memory usage by Flyweight Pattern based Solution.

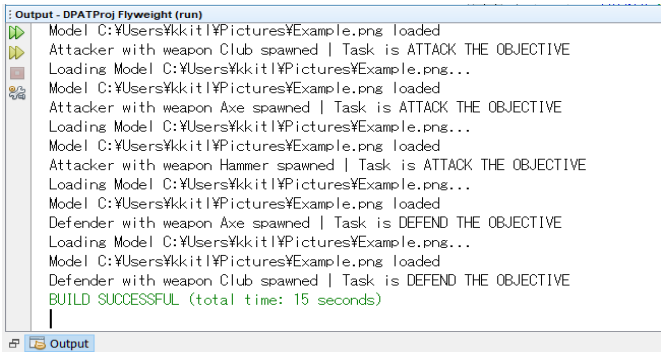

Fig. 22. Execution Time Taken by Flyweight Pattern based Solution.

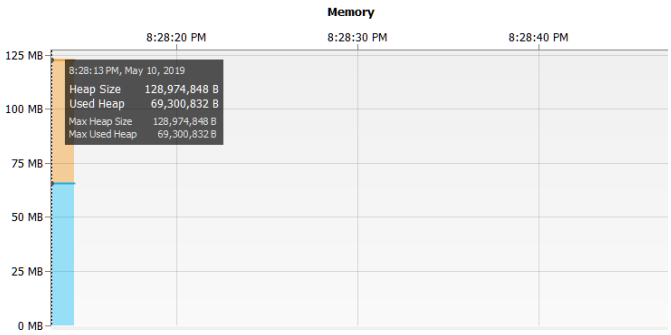

Fig. 23. Memory usage by Proxy Pattern based Solution.

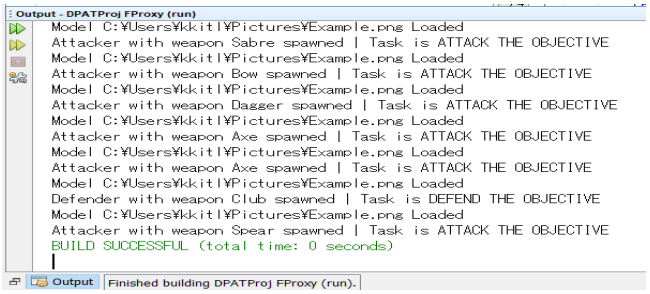

Fig. 24. Execution Time Taken by Proxy Pattern based Solution.

Fig. 25 and Fig. 26 show the comparison of the three solutions using a bar chart in order to better illustrate the impact of the design patterns.

From the results above, it is obvious that both design patterns have significantly lowered the execution time as well as the memory usage. Applying the flyweight pattern has lowered the memory usage by 349MB while applying proxy pattern has further lowered the memory usage by 519MB. Both design patterns have also shown a significant decrease in the execution time which is 15 seconds.

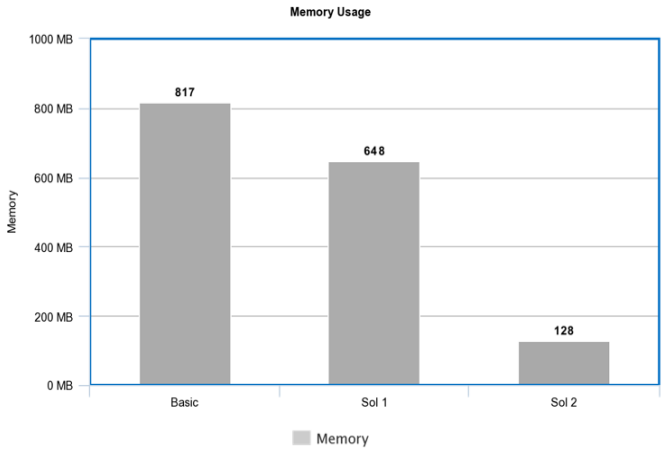

Fig. 25. Memory usage Comparison.

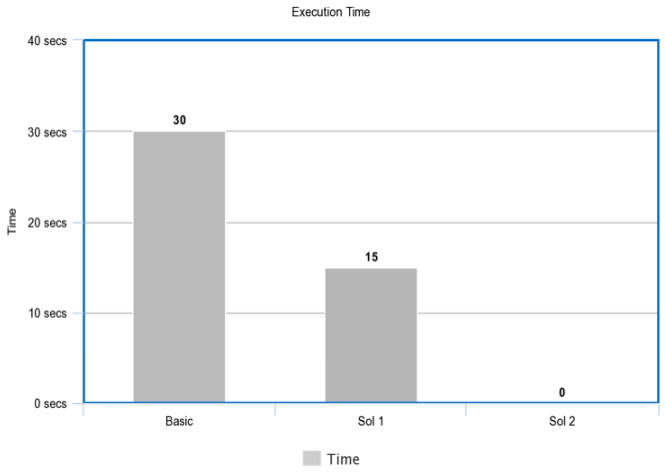

Fig. 26. Execution Time Comparison.

V. Conclusion

Throughout the context of this research, the impact of efficiency on software systems is explored and examined and later evaluated using a simple imitation of an online shooter game. This research also analyze the effectiveness of applied design refinements on efficiency of a system. The design refinements were carried out by applying Flyweight and Proxy design patterns on a simpler solution. In conclusion, Flyweight and Proxy design patterns can both be very effective at increasing the efficiency of a system by decreasing the execution time and memory usage provided they are implemented in the right context.

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Micro Agent and Neural Network based Model for Data Error Detection in a Real Time Data Stream

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***Abstract*—In this paper, we present a model for learning and detecting the presence of data type errors in a real time big data stream processing context. The proposed approach is based on a collection of micro-agents. Each micro-agent is trained to detect a specific type of error using an atomic neural network based on a sample multilayer perceptron. The supervised learning process is based on a binary classifier where the training data inputs are represented by data types and data values. The Micro-Agent for Error Detection (MAED) is deployed at several instances depending on the number of error types to be handled. The orchestration mechanism of data streams to be examined is performed by a special Host Micro Agent (HMA). This later receives in real time a data stream, splits the current record into several elementary fields. Each field value is streamed to an instance of MAED Agent which responds with a signal of presence or not of a specific data type error of the corresponding data field. For each detected data type error, the HMA Agent selects and performs the appropriate cleaning algorithm from a repository to correct the present errors of the data stream. To validate this approach, we propose an implementation based on Framework Deep Learning 4j for the Machines Learning part and JADE as a Multi Agent System (MAS) platform. The used dataset is generated by an events generator for smart highways.**

***Keywords*—Micro-agent; machine learning; errors; big data; multilayer perceptron; stream processing**

I. INTRODUCTION

The emergence of new technologies in recent years, such as sensors, smart cities, the Internet of Things, social networks, e-commerce etc., as well as the evolution of some other technologies of information systems of companies especially in the banking sector, medicine, industry have allowed the generation of a large amount of data. This fast evolution forces companies to evolve their information systems to keep up with the fast pace of data flow whether for processing, analysis or storage.

Several technologies and several lines of research have been proposed to find solutions to the management and storage of this massive data. Among these technologies is machine learning, which has been very successful in recent years in several activity areas such as speech recognition, computer vision and natural language processing [1].

Given the abundance of data flows that we have today, this science (machine learning) has changed dimension and to aroused a great interest of the scientific community which has allowed it to be present in almost all fields.

This abundance of data (big data) represented today by ZettaBytes and tomorrow by PetaBytes-for example according to IDC1 by 2025, the world will create 180 zettabytes of data per year against 4.4 zettabytes in 2013 - allows businesses to exploit machine learning technology in other areas of research to bring new solutions.

But even if we have large amounts of data and high computing power, it will not be enough for companies to make correct predictions to anticipate and make the right decisions. Indeed, the exponential flow of data and the speed of its generation give a high probability of having different types of errors according to the different types of data (Structured "S", Semi-structured "SS" or UnStructured "US") (Fig. 1) manipulated by enterprises and can therefore negatively influence decision-making.

It is therefore essential that the data received by the companies must be of high quality.

Our approach proposes a contribution, in this sense, that helps to improve the quality of data from the large data flows which are intended to decision-making. This approach combines two technologies: machine learning technology and multi-agents systems in order to distribute processing. The main goal is to detect frequent errors in real time in large data streams. This approach also complements our contribution "Frequent Big Data Error Handling Repository" [2].

This approach reveals several advantages as:

- Splitting our problem into smaller, more manageable units.
- Having an extensible model: if a new error is detected, by a manager of the company, and if its frequency of appearance is important, the abundance of the data of the company allows the training and the test of a new ANN to identify this new error.
- Exploiting the concept of machine learning because this branch of artificial intelligence (AI) is becoming widespread.
- Using this approach to all companies not only to giant companies such as Amazon, Facebook and Google but also to other companies that now have big data thanks to unstructured data such as text, sensors and images.

[1]- Michael Kanellos, https://www.forbes.com/sites/michaelkanellos/2016/03/03/152000-smart-devices-every-minute-in-2025-idc-outlines-the-future-of-smart-things/#4c3569df4b63., Mar 3, 2016

- Easy portability of this approach to other companies of different activities;
- Using this approach in information systems by the means of data warehouses and data stores.
- Generalizing this approach to other new situations to improve data quality.

This article is organized as follows: We will begin by giving a background of machine learning and multi-agents systems. After we presented some related work and then we describe the dataset used to train and test each micro-agent. We then detail the proposed model and before concluding, we explain the operation of this approach.

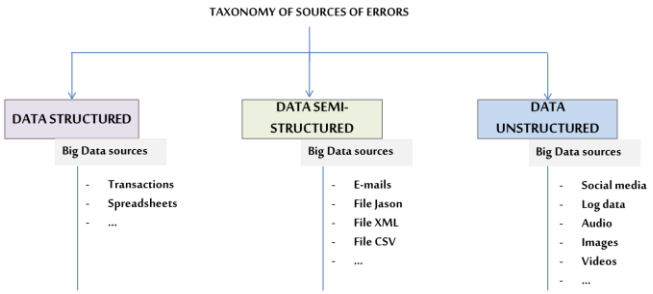

Fig. 1. Taxonomy of different Sources of Big Data Errors [2].

II. Background

A. Machine Learning

Machine learning is a type of artificial intelligence where the machine is able to learn on its own after training based on a large amount of data.

Machine learning uses the network of artificial neurons imitating the human brain. This network is composed of several layers of neurons; its behavior depends on its network architecture. The architecture of a network of neurons can be defined by the following elements [3]:

- Number of neurons
- Number of layers
- Types of connections between layers

Machine learning is used in several areas:

- Automotive,
- manufacturing,
- consumer products,
- finance,
- agriculture,
- energy,
- health car,
- pharmaceuticals,
- public and social sector,
- media,
- telecom,
- transportation, travel and logistics,
- etc.

In this paper we have used the atomic neural network (ANN) for the detection and identification of data type errors in real time big data stream.

We have chosen to use a variant of the perceptron of Fig. 2, the first and the smallest unit of neural networks, as an error detection algorithm to have a minimum level of granularity and to split this problem to small units that allow the extension, integration and to be easy management of our system.

The choice of the initialization of the weights of a neural network is very important because it allows preventing layer activation outputs from exploding or vanishing during training neural network. We chose the method proposed by He et al. [4] which initialization of weights for ReLu is random, but depends on the size of the previous neuron layer. This allows controlling initialization of the weights in order to solve the vanishing/exploding gradient problem.

In fact, we have chosen to use an atomic neural network based on a sample multilayer perceptron. It is composed of three layers of neurons Fig. 3: the input layer, the hidden layer (s) and the output layer.

- The input layer is a set of neurons that carry the data to be processed.
- The hidden layer, very often several hidden layers, is an intermediate part between the input layers and the output layer. This is where the network stores its internal abstract representation of learning data, in the same way that a human brain has an internal representation of the real world[2].
- The output layer represents the end result of the neural network: its prediction.

B. JADE : Java Agent Development Framework

JADE is a multi-agent platform. It is a framework that allows the development of multi-agent systems. It has three modules:

- Directory Facilitator (DF): provides a yellow pages service to the platform.
- Communication Agent Channel (ACC): manages communication between agents.
- Agent Management System (AMS): supervises the registration of agents, their authentication, access and use of the system.

These three modules are activated each time the platform is started.

[2]- Ivan Vasilev, “A Deep Learning Tutorial: From Perceptron’s to Deep Networks”, https://www.toptal.com/machine-learning/an-introduction-to-deep-learning-from-perceptrons-to-deep-networks

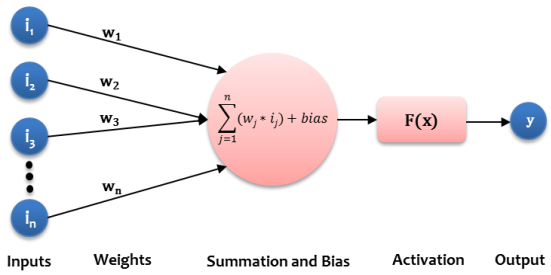

Fig. 2. The First Artificial Neural Networks.

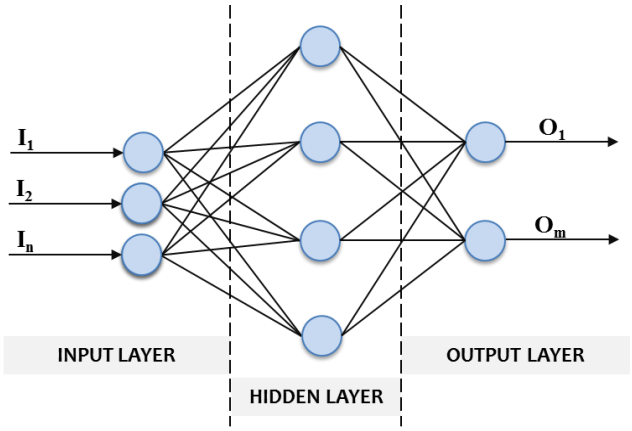

Fig. 3. Architecture of Multilayer Perceptron.

Each JADE instance is called "Container" and can contain multiple agents. The set of containers constitutes a platform. Each platform must contain a special container called "main-container" where all other containers are registered as soon as they are launched. Containers can be run on different machines, creating a distributed platform. Agents in a JADE application perform tasks and interact by exchanging messages (Fig. 10).

The choice of multi-agents in this paper is justified by the following advantages:

- Each agent is responsible for a specific task in the data processing;
- Agents are autonomous and distributed;
- The cooperation between the agents is done by the transmission of messages. They communicate in the same way [5].
- Agents can learn, perceive, reason, judge and make decisions based on their knowledge of themselves and their environment and can cooperate and coordinate through communication [6].

III. Related Work

Since the advent of Data Warehouse and Data mart, which were among the first data sources for decision-making, several research projects were proposed to improve the quality of data and to ensure reliable decision-making, such as In [7], the authors proposed hierarchical Framework compound of dimensions, of characteristics and of quality indications, and on the basis of which they built a process of dynamic evaluation of the quality of the data of flows Big Data.

In [8], authors proposed a solution which allowed the evaluation of the quality of the data of the social media in every phase of processing in the architecture Big Data and the improvement of the decision-making by supplying data validated in real time for the user.

Other authors [9] proposed a novel unsupervised real-time anomaly detection algorithm. The technique is based on an online sequence memory algorithm called Hierarchical Temporal Memory (HTM).

To our knowledge, the relationship between machine learning, multi-agents and the quality of big data flows is very rare. Lately, there are some new researches, as in [10] which show how machine learning can increase the efficiency and cost-effectiveness of measures of error identification and correction using learning algorithms supervised and how machine learning can help overcome the lack of data.

The article [11] uses a method of prediction of traffic flows based on deep learning that is also an artificial intelligence technique that considers the spatial and temporal correlations inherently.

Another article [12] that talks about a point view on the problems of the quality of big data flows and which states that research in this problem will be specific to each sector. This is what we propose in this paper: detection of errors of big data flows for a company of a given sector of activity.

We have therefore thought to create a relationship between these technologies (machine learning, micro-agents) to make a contribution to this problem of data quality omnipresent in companies.

IV. Data

In this paper, the dataset used to train and test each micro-agent are based on the data generated by the spatio-temporal traffic event generator for real road networks [13]. In the real case the considerable number of sensors used in highways generates large, fast and real-time data flows, especially if the density of the sensors is high enough. So, the analysis and exploitation of these data can be used to Anticipate and predict how to control the traffic of each highways axis and consequently help to make the right decisions to save lives.

To train our micros-agents, we took in our case a single XML data file that represents the vertices (vertex.xml) of the event generator [13]. These data are characterized by the following attributes:

- name: Sensor identifier (ID)
- type: Element type (Enumeration : I (Entrance), IO (Entrance/Exit), X (Exchange), R (Service Area), T (Toll), S (Sensor), O (Exit)
- label: Name of the highway (string)
- locality: The locality name of the sensor position (string)

- long: Longitude (double)
- lat: Latitude (double)
- factor: Attendance factor.

V. Proposed Model

Data errors are often related to fields and records Fig. 4. We have proposed two approaches Fig. 5 in order to detect errors. In this paper, we have chosen to describe and to develop the first approach. It allows detecting the presence of data type errors in a real time big data stream.

The second approach will be the subject of a future paper. It consists to detect errors in the data in the records. These errors are often related to referential integrity, duplicates and other errors.

The approach proposed in this article, therefore, aims to detect frequent errors in real time in each elementary field. It is based on machine learning technologies and micro-agents (the choice of the term "micro" refers to the level of granularity of the tasks of each agent). The relation these two technologies will allow us to use the same concept for all error detection algorithms. The idea is to associate each micro-agent with an atomic neural network trained, tested and serialized in a file in order to detect a specific error for a single type of data. We will have in the repository of the company a collection of "intelligent" micro-agents and will be distributed for the detection of errors specific to each attribute.

The multilayer perceptron used in our approach, represented by Fig. 6, is composed of two inputs, hidden layers and an output layer.

A. The Input Layer of Each ANN

Since data from big data streams are heterogeneous and of different types (Structured "S", Semi-structured "SS" or UnStructured "US"), we have assigned to each data type a value that will be used in our approach to differentiate between data types and their errors. Table I shows an example of the data types and their values.

We need to use for this layer, two inputs for each multilayer perceptron:

- The data of a single attribute of the data flow.
- The data type of this attribute.

The idea of using a single multilayer perceptron for a single type of error of a data type is the decomposition, distribution, and standardization of error detection tasks. Indeed, once the flow of the data arrives, the Host Micro Agent (HMA), which is at the reception of these data, splits the current record into several elementary fields. Each elementary field will be the first input of the corresponding atomic neural network.

The second input is none other than the data type of each attribute chosen by the same micro-agent (HMA) from the types of data stored in the company repository (Fig. 7).

It is these two data, plus the types of data errors, stored in the enterprise repository (Fig. 7) that represents the dataset used to pass each multilayer perceptron through three stages before they are used:

- The training of each ANN;
- The test of each ANN;
- Serializing each ANN so that it will be ready for use.

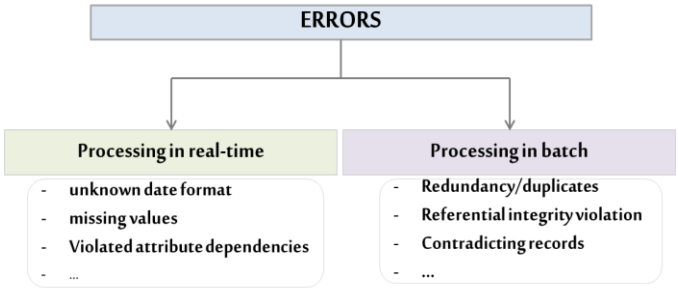

Fig. 4. Types of Errors.[2].

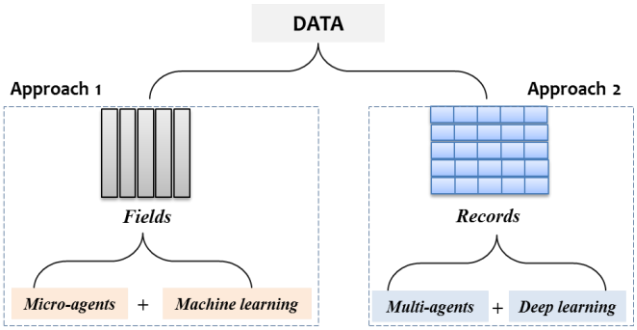

Fig. 5. Proposed Approaches.

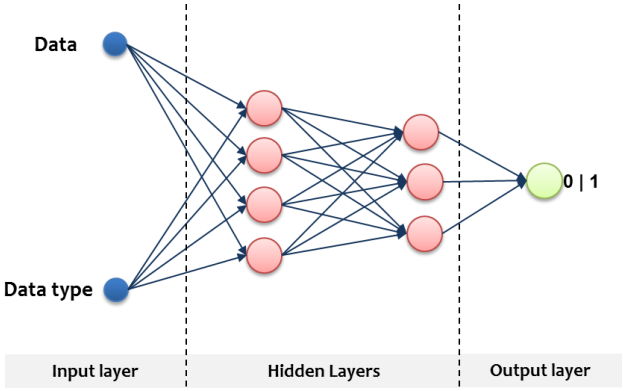

Fig. 6. Multilayer Perceptron Architecture used in this Approach.

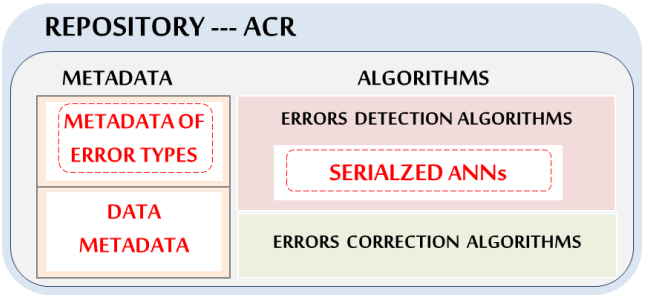

Fig. 7. Big Data Frequent Error Management Repository [2].

TABLE I. DATA TYPES

Data Type	value
Integer	1
double	2
String	3
Date	4
Boolean	5
Image	10

B. Training and Testing of ANNs

The training and testing steps were limited earlier by the lack of data and the slowness of the processors. Now with the abundance of data (Big Data), and the technological evolution such as processors speed and distributed and parallel processing, the companies can use them in order to have "intelligent" ANNs trained in a reasonable time to improve the quality of the data.

The steps mentioned above are essential in our approach, because we will only serialize neural networks which have a high accuracy rate, after variation of the number of hidden layers, during the training and test operation.

The datasets in Tables IV and VI present examples for training and testing some micro-agents.

Table II provides an example of a dataset for the "long" attribute of double type. The corresponding ANN will be trained to detect the missing value error of this attribute. The choice of the type of error is explained in the section: Instances of micro-agents.

Table III gives an example of a dataset for the "type" attribute of type String. The corresponding ANN will be trained to detect the “check constraint” error of this attribute containing enumerated data.

TABLE II. DATASET FOR THE "LONG" ATTRIBUTE

Inputs		**Outputs**
long : Longitude	***Data type***	
-6.83255	2	0
-7.6113801	2	0
5.599	2	1
	2	1
-7.9999399	2	0

TABLE III. DATASET FOR THE "TYPE" ATTRIBUTE

Inputs		**Outputs**
type	***Data type***	
I	3	0
R	3	0
IIO	3	1
r	3	0
B	3	1
H	3	1

C. Instances of Micro-Agents

Once the micro-agent HMA separates the current record into fields, this micro-agent looks for the types of errors of each type of data in the metadata stored in the repository of company.

Table IV shows an example of metadata of the types of errors related to each type of data. This metadata stored in the repository, will be used in our approach so that the micro-agent HMA deploys several instances of micro-agents according to the number of errors of the same data type. For example, if we have in a data stream, N attributes of type "String" with M errors stored in the repository, the micro-agent HMA will deploy M*N instances of the micro-agents for detection possible errors of the type "String". It will do likewise for the other data types of this same flow of data by running the other micro-agents instances.

D. Serialization of ANNs

Serializing neural networks of machine learning in files is the last step in our approach before they are used. It makes it possible to associate each ANN with a micro-agent. This step depends on scores obtained after the training of each multilayer perceptron and its test.

Tables V and VI, there are examples that explain the link between errors of each data type, serialized ANNs, and instances of micro-agents.

For example, the "Check constraint" error of the "double" type serialized under the name "ANN_21" associated with the micro-agent MAED_21 to detect error of this data type. The instance "ANN_32" associated to the micro-agent MAED_32 serves to detect "check constraint" error of data type "String".

TABLE IV. METADATA OF ERRORS OF EACH TYPE OF DATA

Data types	**Errors**
Integer	Missing value
	Error format
	…
Double	Missing value
	Error format
	…

TABLE V. INSTANCES OF MAED THE DOUBLE TYPE

Errors	**ANN serialized**	**Instances MAED**
Check constraint	ANN_21	MAED_21
Error Type	ANN_22	MAED_22
Null	ANN_23	MAED_23

TABLE VI. INSTANCES OF MAED THE TEXT TYPE

Errors	**NN**	**MAED**
Null	ANN_31	MAED_31
Check constraint	ANN_32	MAED_32
Error Type	ANN_33	MAED_33

E. The Hidden Layers of ANN

The number of neurons in the layer is the strength of machine learning because during the training and testing stages of each ANN the number of these layers is varied to have very high levels. Indeed, some results highlight the interest of considering two or more hidden layers to obtain more parsimonious and more efficient networks, by composing several levels of non-linearity [14].

F. The Output of ANN

The output layer of our multilayer perceptron is binary. It corresponds to two states. If the data in the field contains an error, they will be represented in the data set as "1". Otherwise, if this data does not contain errors it will be represented by the value "0". See the example in Tables II and III. We have chosen supervised learning that allows the ANN to learn from each example with the aim of being able to generalize its learning to new cases.

VI. Operation of this Approach.

The operation of our approach is detailed in the following two sections:

A. Using the Host Micro Agent (HMA)

The use of multilayer perceptron (ANN) is related to micro-agents guarantee distributed and parallel execution. Each micro-agent associated with an ANN constitutes a single unit to perform a specific task. Among these micro-agents we have the Host Micro Agent which receives the data flows of the sensors in real time. Each sensor of our event generator [13] sends a data intercepted by the framework Kafka Streams Fig. 8. At the output, after transformation and aggregation of the data, the HMA will support the data flows and perform the following tasks:

- After the reception of the data flows HMA splits the current recording into fields (attribute).
- Searches the data type of each attribute in the repository metadata (Fig. 7).
- Adds each attribute to its data type so as to form the inputs of the corresponding neural network.
- Searches in the repository of the company the types of errors of each type of data in order to choose the appropriate micro-agents.
- Depending on the number of error types of each data type, HMA deploys the necessary number of instances of the micro-agents.
- HMA distributes the instances of micro-agents in multiple machines to ensure task distribution.
- For each elementary data, it requests parallel execution of all micro-agents to detect any errors.
- On reception of the result, if an error is detected, that is to say that agent HMA receives a positive answer "1" it searches for in the repository of the company the appropriate correction algorithm. In this case, the agent HMA is informed that the sensor that sent the data is damaged. Automatically, it will run a virtual sensor [15] that will provide data from historical data until the physical sensor is repaired.

Fig. 9 shows the arrival of a data flow, the HMA splits it into several attributes and deploys, depending on the number of errors of each attribute, several instances of micro-agents.

For example, the instances of micro-agents linked to the serialized multilayers perceptron's (MAED_31, MAED_32 etc., MAED_3n) are deployed to detect any errors of the attribute "type: String". It's the same for the other attributes "long", "locality", etc.

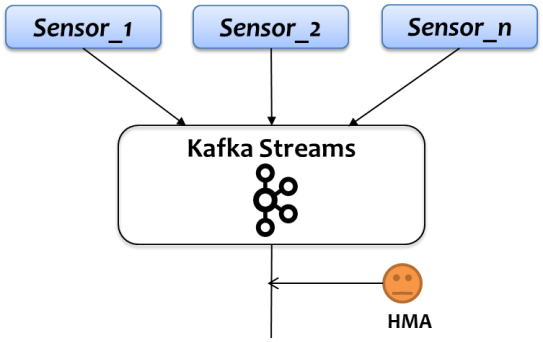

Fig. 8. Receipt of the Data Flow by HMA.

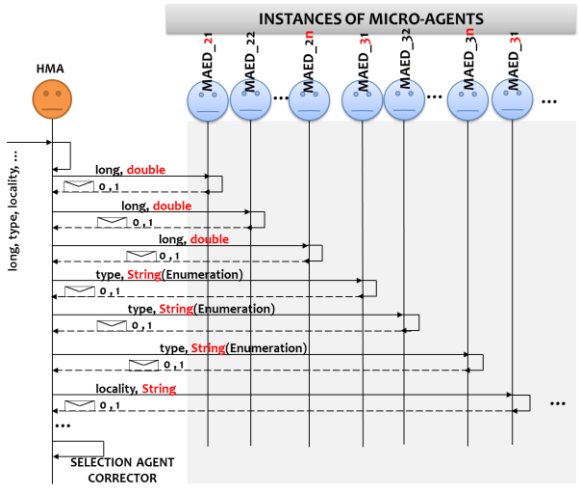

Fig. 9. Using the Host Micro Agent.

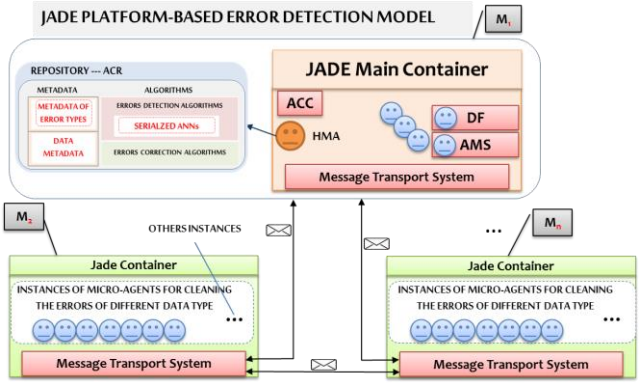

Fig. 10. JADE Platform-based Error Detection Model.

B. Multi-Agent System for Error Detection

The JADE platform chosen in this paper is used to distribute errors detection tasks. The Host Micro Agent distributes instances of micro-agents in multiple machines.

This platform allows having identical instances of micro-agents. Fig. 9 shows an example of these identical instances such as " MAED_31" deployed by the HMA because we have two attributes of the same type "type: String" and "locality: String".

Fig. 10 shows the content of the platform of our approach and the operation of the instances of micro-agents on several machines. In the machine "M1", for example, one finds "JADE Main Container" that must be started to be able to deploy the host micro agent HMA. We also find on this machine the enterprise repository containing in particular the metadata of the types of error, the data metadata, the serialized multilayers perceptron's and the algorithms of correction.

In the other machines there are still other instances of the micro-agents of detecting errors. For instance, the machine "M2" contains instances of detecting errors of some data types such as "Integer", "String", etc. Other detecting errors instances will be distributed to other machines to speed up processing.

VII. Conclusion

In this paper, we have proposed a model for learning and real-time automatic detection of errors existing in a big data stream. The used supervised learning process is based on a binary classifier where the training data inputs are represented by data types and data values. This approach relies on a collection of micro-agents that guarantee distributed and parallel execution. Each micro-agent is linked with a sample multilayer perceptron which is trained, tested and serialized (ANN) in order to perform a single task: detect a single error of a single type of data.

The Host Micro Agent (HMA), in this approach, receives the flow of data and separates the current record into several elementary data (field). Then, it searches in the enterprise repository for the data type of each attribute to compose the multilayer perceptron entries. This data will be supplemented by the types of errors sought by the agent "HMA" starting from the metadata. In the end, it will deploy the necessary number of instances of the micro-agents and distribute them on the machines of the system.

When the agent HMA receives a message containing an error, it selects and runs the appropriate cleaning algorithm from an enterprise repository in order to correct the existing error.

Our approach is extensible because we can train other micro-agents for possible new errors. It is also easy to integrate into other areas of activity since the micros agents are very small units that are easy to set up and manage.

The first results after load they micro-agents are satisfactory especially for the errors cited in this paper.

In perspective, we will detail "approach 2" figure by applying the concepts: multi-agents and deep learning to detect errors related to records such as duplicates, errors related to referential integrity, etc.

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An Automatic Multiple Sclerosis Lesion Segmentation Approach based on Cellular Learning Automata

A Case Study

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***Abstract*—Multiple Sclerosis (MS) is a demyelinating nerve disease which for an unknown reason assumes that the immune system of the body is affected, and the immune cells begin to destroy the myelin sheath of nerve cells. In Pathology, the areas of the distributed demyelination are called lesions that are pathologic characteristics of the Multiple Sclerosis (MS) disease. In this research, the segmentation of the lesions from one another is studied by using gray scale features and the dimensions of the lesions. The brain Magnetic Resonance Imaging (MRI) images in three planes (T1, T2, PD) (weighted) containing MS disease lesions have been used. Cellular Learning Automata (CLA) is applied on the MRI images with a novel trial and error approach to set penalty and reward frames for each pixel. The images were analyzed in MATLAB and the results show the MS disease lesions in white and the brain anatomy in red on a black background. The proposed approach can be considered as a supplementary or superior method for other methods such as Graph Cuts (GC), fuzzy c-means, mean-shift, k-Nearest Neighbor (KNN), Support Vector Machines (SVM).**

Keywords*—Multiple Sclerosis (MS); MATLAB; Magnetic Resonance Imaging (MRI); MS Lesions; Cellular Learning Automata (CLA); Segmentation; Support Vector Machines (SVM)

I. Introduction

Multiple Sclerosis (MS) is a demyelinating nerve disease which for an unknown reason assumes that the immune system of the body is affected, and the immune cells begin to destroy the myelin sheath of nerve cells. In Pathology, the areas of the distributed demyelination are called lesions that are pathologic characteristics of the MS disease [1], [3].

Statistics show that over 2.5 million people in the world happen to suffer either of the stages of Multiple Sclerosis (MS). Fundamentally, the disease tends to erode the insulating myelin sheaths which surround the axons of the brain of an individual. It is correct to note that the disease happens to affect different people based on their anatomy. The statement implies that ounce a person has been diagnosed with MS then one may face the relapse and the remission periods at different rates. Plaque detection of MS can be perceived as a transformative step that has aided in spotting the type of MS and start the appropriate treatment during the early stages. The statement implies that having proper imaging techniques provides a clear visual analysis of the situations and thus the proper forms of medication can be administered during the early phases. Therefore, this research paper aims to assess the how MS detection has been enhanced and improved using the different forms of digital image processing. Multiple Sclerosis (MS) is a disorder which happens to affect the immune system of an individual and the traumatizing aspect is the fact that it eats or erodes the protective covering of the nerves. The disorder has many symptoms which are evident especially in the early phase because it affects the central nervous system. In this case, treating MS by making use of digital image processing is a technique which has enabled health practitioners to curb the effects of multiple sclerosis in individuals. It is correct to point out the evolution of digital imaging has provided the health practitioners an easier time in diagnosing the status of individuals and providing them with proper therapeutic channels. There are various issues which affect the functioning and the operations of the nerves and thus, the evolution of such technological mechanisms has been a major booster in coming up with appropriate ways of addressing the existing health issues. Examples of such disorders include Multiple Sclerosis.

Multiple Sclerosis (MS) cannot be diagnosed well by CT scan because the lesions are not clearly visible, but it is well diagnosed through MRI imaging. Since the immune cells around the blood vessels have more access to the nervous tissue, in MR imaging method, MS disease lesions are usually seen around the blood vessel. Because the MS disease lesions are only detectable by using MRI imaging, it has been employed in this research including T1, T2, and PD images (MICCAI Grand Challenge 2008 dataset)[1], for MS lesions extraction [1], [3], [8]. Assessment of the proposed method is performed on the MICCAI MS Lesion Segmentation Challenge 2008 dataset.

The prevalent MRI species for the distinction of MS lesions are T1-weighted[2], T2-weighted[3], Proton-density-weighted (PD-weighted)[4], fluid-attenuated inversion recovery(FLAIR). Unfortunately, the last one (FLAIR type) has a long acquisition

[1] MICCAI is the annual international conference on Medical Image Computing and Computer Assisted Intervention
[2] T1-weighted (maximum T1 contrast shown)
[3] T2-weighted (maximum T2 contrast shown)
[4] Proton density (PD) weighting (density of hydrogen protons shown)

time and may not be accessible for every patient [9]. Therefore, our proposed method is implemented by T1, T2, and PD image types.

In recent years, MS plaque detection based on color has attracted the attention of the many scholars for its low computational complexity. Most of these methods have a high error rate for not taking it into account the texture of the lesion. In this article, a novel method to detect MS lesions is proposed. This method combines the image information in the gray area and texture, detects the skin area by using Cellular Learning Automata (CLA) [10], [11], [12].

Cellular Learning Automata (CLA), the combination of Cellular Automata (CA) and Learning Automata (LA), is preferable to both CA and LA individually [4], [16]. Unlike CA or LA, CLA tries to learn optimal actions and it can improve the learning capability by using a set of learning automata that interact with each other. In addition, CLA can optimize outside standard sequential processes mapping real world solutions more accurately [2], [5], [16].

Firstly, the candidate lesion regions are detected through defining a threshold, and then these regions are assigned to a texture analyzing system. The output of texture analyzing system is the probability rate of being lesion for each pixel. Then this probable mapping is given to a CLA. By using neighborhood relations and texture information, CLA converges to a steady state representing the final output of the proposed system.

II. Background Studies

Clustering according to the learning automata:

Clustering can be considered as the most important method in unsupervised learning. In clustering, the concern is to divide the data into clusters so that the similarity among the data of each cluster is at its maximum, and the similarity within the clusters is at its minimum. Clustering follows an iterative procedure that tries to estimate the followings for a considering number of constant clusters: obtaining some points as the centers of the clusters, that in fact these points are the means of the points belonging to each cluster. Assigning each sample data to a cluster where the data was closest to the center of the cluster [4], [12]. In the simplified type of this method, first, depending on the number of required clusters, some points are randomly chosen. Then, the data are assigned to one of the clusters according to their nearness (similarity), and thus new clusters are formed. By repeating this procedure, in every iteration, through obtaining the mean of the data, new centers can be calculated for the data, and they can be assigned to the new clusters again. This procedure would go on until no change would take place among the data. The following function (1) is known as target function [6], [10], [14], [15].

$$j = \sum_{j=1}^{k} \sum_{i=1}^{x} \left\| x_i^{(j)} - c_j \right\|^2 \quad (1)$$

III. Cellular Learning Automata (CLA)

CLAs are a mathematical model for the systems that are dynamic, complex and consist of very simple components, which have learning capability, and behavior of each component is determined and corrected by the behavior of its neighbors and its past experiences. The simple components which form this model can show a complex and powerful behavior through interacting with one another [12], [13], [14].

Pixel based methods judge whether a pixel is a lesion pixel only by its color, while region based methods combines color and texture information [11]. Since using neighborhood and texture information can be practical in the skin detection, and since CLA can easily use neighborhood information [12], it can therefore be a suitable candidate to be employed for lesion detection. CLA is composed of the components that are in the same neighborhood and the behavior of these components is defined according to the current behavior of their neighbors and their own and their neighbors' experiences (reward and punishment that they receive for their actions and reinforcement signals that they receive from environment).

CLA is a hybrid model of two, learning automata and cellular automata. In the following these two models are discussed. Cellular automata are a mathematical model that can be used for the simulation calculations of the systems. Cellular automata are simple discrete systems that can exhibit complex calculations and behavior through simple and local rules. Locality in the cellular automata means that in determining the new value of each cell, the cells in its neighborhood are used and more distant cells would have no usage. Each cell has a set of states for itself and at every moment, according to its own state and the state of the neighbors, it decides to what state it goes. State switch rules are constant for cellular automata and never change. Cellular network can have different dimensions and be one, two or multi-dimensional [11]. According to the values that cells can possess, cellular automata are classified to two types of binary and multi-valued. Understanding the behavior of the cellular automata from its rules is very difficult and requires simulation. One of the problems of using cellular automata is designing rules that perform our desired action [13]. There are different types of cell updating rules that cause different types of cellular automata to be generated. For example, the rules can be expressed in probabilistic and deterministic forms and these two types of rules lead to two types of deterministic cellular automata and probabilistic cellular automata. Characteristics of the cellular automata can be briefly expressed as follows: automata are homogeneous and updating would be performed synchronously. Of course, asynchronous updating would also be possible, i.e. we start updating from one corner of the network and continue to the end, while in the synchronizing state, all the cells become updated according to the previous state of the neighbors not according to their present state. Dominant rules are defined according to the neighbors of each cell, and can have deterministic or probabilistic form. Learning automata are applied in cases such as physical processes simulations like Brownian motion, dissolution, social processes simulation like rumor dissemination, chemical phenomena simulation like fire spread and iron corrosion, image processing, random number generation, and cryptography [4], [10], [12]. Given its rules,

learning automata can show complicated behaviors. Rules in the learning automata can be defined as a bit string in which each bit represents the next state corresponding to the number of the bit [2], [5].

IV. Learning Automata

The process by which living creatures learn different subjects has for long time attracted the interest of the specialists. The research conducted on this ground focuses on two general categories: understanding the process through which living creatures attempt learning. Obtaining methods by which this learning ability can be created in the machines [11].

Learning is defined in different ways. Therefore, learning is defined as applying a series of modifications in the system efficiency, according to the past experiences. The most important characteristic of this learning system is its ability to increase efficiency during the time. To express this definition in a completely mathematical way, we should say: the objective of a learning system is to optimize an action that is not possible to be completely recognized. By this definition, the function of learning system can be reduced to a matter of optimization that is defined on a set of parameters, and can be solved by obtaining the set of optimal parameters through the existing methods. Learning automata method in learning is defined as determining the optimal action from among a limited set of predetermined actions that are capable of being performed in a random environment. Automata are assumed to work in an unknown random environment [11], [12]. At every moment it chooses an action from its action-set and notifies the environment. In response to the performed action, environment produces an output from the set of defined outputs (that can be limited or unlimited) and notifies the automata, and after receiving the response of the environment, the automata update their decision-making method for selecting next action. It is assumed that there is a probable relation between each automaton action and the response of the environment, and this relation is, in fact, the internal characteristics of the environment and is recognized by the automata during learning. Learning automata theories analyze the automata that work in such environment [14], [15].

Fig. 1 shows the relation between LA and the environment. An action randomly selected as a sample of action probability distribution. The selected action is then used in the environment [17]. The environment responds to the taken action in turn with a signal called reinforcement signal. Afterward, the action probability vector is updated based on the reinforcement signal feedback from the environment.

In the 1960s, a method was introduced to simplify the existing problems in the engineering systems to a problem of identifying optimal parameters and applying hill climbing methods to solve it. Learning automata that worked in a random environment is considered as a model for learning. In the conducted researches, using learning in the engineering systems was also considered.

a) Irregular Cellular Learning Automata (ICLA): Irregular cellular learning automata (ICLA) are cellular learning automata (CLA) which remove the restriction of rectangular grid structure in traditional CLA. There are number of applications which cannot be adequately modeled with rectangular grids. Each pixel represents a cell that is equipped with a learning automaton. Learning automata are in fact a specific cell that determines its state according to action probability vector [7], [11], [14].

b) Proposed algorithm: In many matters, learning cannot be correctly operated by using one learning automaton, but the learning automata manifest their main power when employed collectively. Given this issue and the defects enumerated for cellular automata, by combining these two models, a new model called cellular learning automata was generated. To use the algorithm, we first need to have an initial image from the location of the MS plaque (Fig. 6). The main objective of employing cellular learning automata is making use of neighborhood relations among the pixels of pseudo-skin regions to increase the efficiency [10], [14], [18]. This is because a pixel doesn't necessarily denote the concept of being a plaque by itself, and a set of pixels can define a skin region in a better way (Fig. 2 to 5). The penalty and reward of each cell are according to the action chosen by the central automata and its neighbors. If the number of the cells that choose the appropriate action for plaque detection is more than 7, the central automata will be rewarded. Therefore, if seven automata detect a texture as plaque, the region around the central automata is taken as plaque region. If the number of these automata is less than 4 (Fig. 4 and 5), the central automata will be penalized [12], [13].

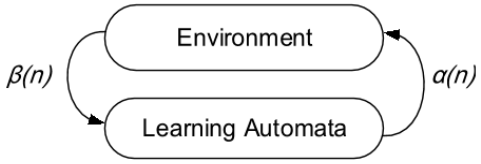

Fig. 1. Interaction between Learning Automata and the Environment [15].

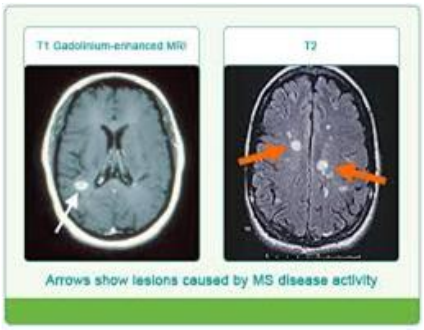

Fig. 2. MS Disease Lesions.

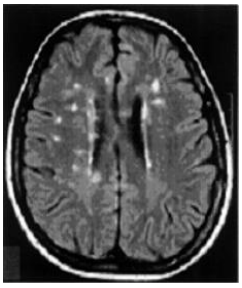

Fig. 3. Image Sample of MS.

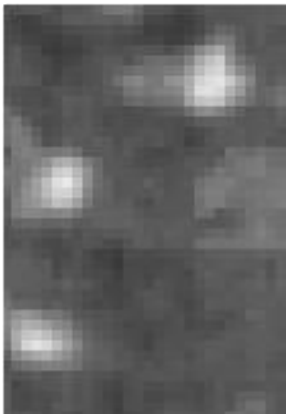

Fig. 4. Infected Sample.

The output result will be as below:

Fig. 5. The resulted image in MATLAB

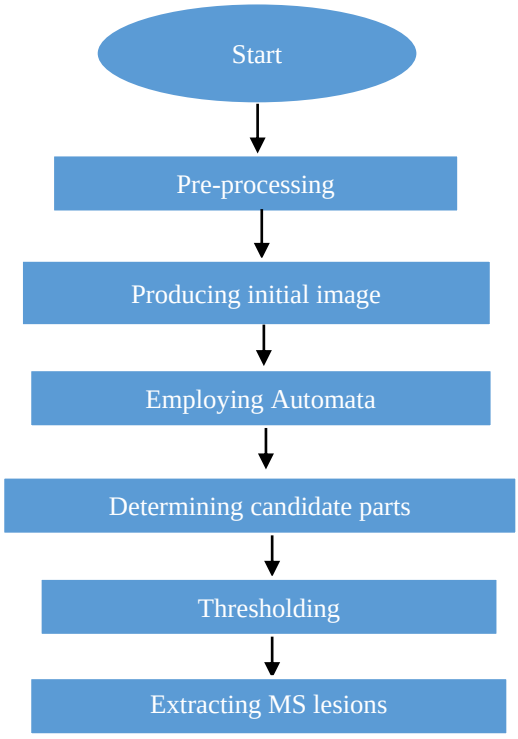

Fig. 6. Block Diagram Illustrating the Proposed Algorithm.

The proposed algorithm

The Pseudo algorithm of the proposed algorithm is as follows:

```
Function (plaque detection function using
cellular learning automata)

Establish an associative CLA.
Initialize the state of cells in CLA.
 for each cell j in the CLA do
  Let x be a data sample from the data set,
give x to cell j
Let i be the class of data x
Cell j selects an action αj
  if Cell j is in row i then
    if αj = 1 AND half or more neighbors of
cell j selects action 1 then
     Reward the selected action of LA in the
cell j
      else
       Penalize the selected action of LA in
the cell j
    end if
      else
    if αj = -1 AND half or more neighbors of
cell j selects action -1 then
   Penalize the selected action of LA in the
cell j
      else
    Reward the selected action of LA in the
cell j
    end if
  end if
end for
```

V. Results and Conclusion

Using databases of the MS images, the images are chosen that have desirable condition regarding the plaques information. For the rate of detection, a formula is used to calculate the percentage error: pixels mistakenly detected as plaques to the total percentage of the detected pixels (Fig. 5). The aforementioned-phrase is the assessment factor for the percentage error (Fig. 7), (Table I), and this formula was examined in 40 images of the database and on average, the percentage error is as follows.

TABLE. I. Analyzed Images

Number of the analyzed images	Error rate in finding the pixels that were mistakenly detected as plaques	Error rate in finding the pixels that mistakenly weren't detected as plaques
40 images	10%	7%

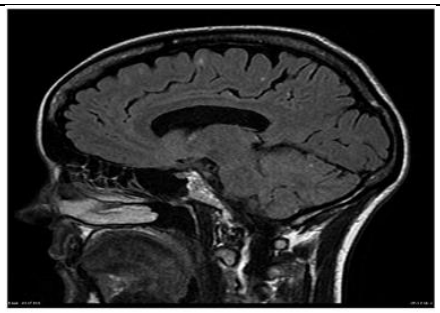	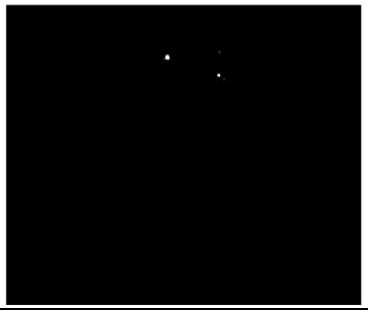
Image Sample of MS1 plaque	**Output image of MS1 plaque using cellular learning automata**
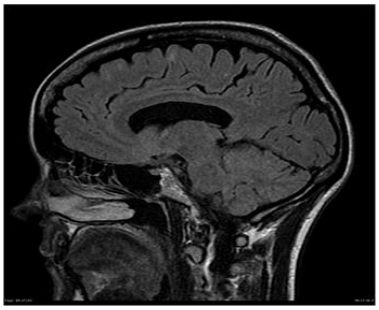	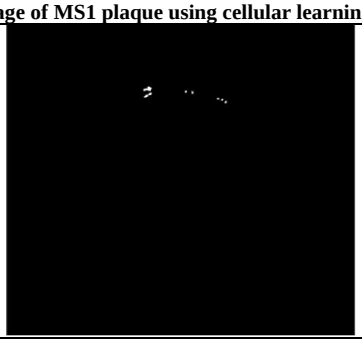
Image Sample of MS2 plaque	**Output of image MS2 plaque using Cellular learning automata**
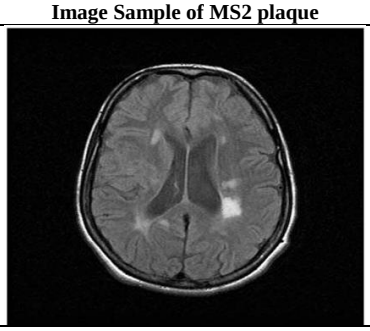	
Image Sample of MS3 plaque	**Output of image MS3 plaque using cellular learning automata**
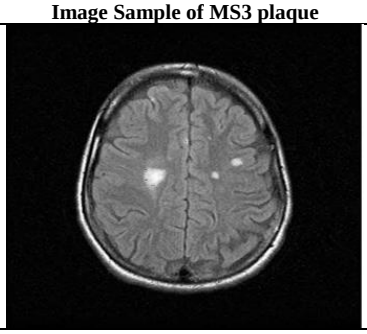	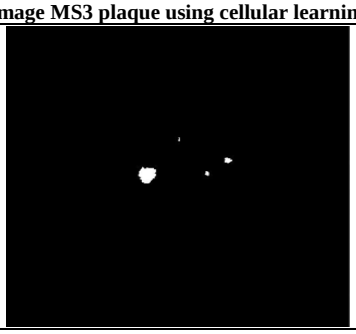
Image Sample of MS4 plaque	**Output of image MS4 plaque using cellular learning automata**
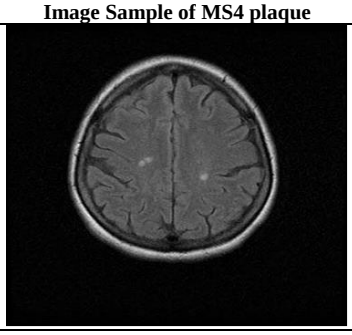	
Image Sample of MS5 plaque	**Output of image MS5 plaque using cellular learning automata**

Fig. 7. MS Images-Analyzed Images.

The pixels depicting MS plaque can be found in the image. By visual inspection, the plaque regions are specified by 1 and other regions are specified by 0. Using ROC command in MATLAB, ROC curve is plotted which is as it is presented below. This curve is used to compare two classification methods. Its Vertical axis is the true positive rate (TPR) and its horizontal axis is the false positive rate (FPR).

This curve represents the tradeoff between TPR and FPR for the two-classed classification of MS and healthy plaques. To plot the curve, we assume a threshold; values above the threshold will be considered as "yes" and values below "No".

Conclusively, it is evident that there are various techniques which can be applied in MS plaque detection using the various imaging aspects. From the research paper, it is clearly obvious that there are various mechanical and operational advantages and disadvantages which emanate from the use of the systems. In addition, the health practitioners need to have a working knowledge of the different systems so that they can be in different positions to adequately deliver as per the required levels. Each technique has its specific advantage and disadvantage and thus, as a health practitioner one need to affirm the best mechanism to set in place based on the gravity of the situation. Primarily, all these aspects can be used in a health institution and it is recommendable for one to have enough background knowledge of the patient before deciding to embark on a specific venture.

VI. Future Work

This case study is limited to an existing database and university, and it reflected the result of a certain set of images in a known repository. In the next paper, near future, the SVM process and techniques can be conducted on a larger scale of images to determine factors influencing current results and lacks using SVM. This will help to understand the efficiency of these techniques and may lead to better results.

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A Constraint-based Approach to Deal with Self-Adaptation: The Case of Smart Irrigation Systems

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***Abstract*—Smart irrigation is a specific application of the IoT, where devices composed of sensors and actuators, collect environmental data, like soil humidity, air temperature and brightness, in order to lunch or plan irrigation cycles. These systems function according to a configuration that dictates the way in which every component should operate. Static configurations are limited, as they only represent a set of fixed requirements. However, in domains such as the IoT, technology is continuously evolving, and various users, sometimes with various needs, interact with the system. This leads to dynamic requirements, which are fulfilled by dynamic configurations. This purpose uses the case of an irrigation system to illustrate such requirements, and proposes a constrained-based approach to design self-adaptive smart irrigation systems.**

Keywords*—IoT; irrigation systems; smart; constraint; product lines; self-adaptive systems

I. Introduction

Irrigation is the application of water to a farmed land, to accompany the growth of plants. Efficient irrigation is the main key enabler for durable and profitable agricultural production. Along with the composition of the soil and the temperature and brightness of the environment, the amount of water administered to a plant is crucial to its prosperity. The term "irrigation system" essentially refers to a device or a machine that (semi) automates the process of irrigation, like drip lines, sprinklers or center pivot irrigation systems. Aside from the ones that still require man force, these devices are programmed to water a surface with a specific amount of water, at a certain frequency, or when instructed to do so. These "traditional" irrigation methods have proved wasteful, and in some cases, ineffective. Thus, the need for a controlled alternative, which answers to real time needs.

Smart irrigation systems (SIS) refer nowadays to all of the above, and they are concerned with various aspects of the agricultural process; soil fertility, temperature and brightness monitoring and adjusting, and humidity management, of both soil and air. This can be attainable by assembling a variety of smart devices, like humidity sensors, temperature sensors, brightness sensors, cooling systems, adjustable bulbs, humidifiers, various irrigators, etc. All of which have the ability to communicate, interact with the environment, and in some cases, modify it. Hence, smart irrigation systems became one of the leading applications of the Internet of Things (IoT) [1]; a paradigm that connects smart devices to enable services from the most basic ones to the most complex, innovative and sophisticated. Today's irrigation systems can monitor real time indicators, like the humidity, temperature or brightness, and react accordingly. Depending on the planted plant, and its requirements in terms of moisture, heat and light, an irrigator can regulate the soil humidity, an air conditioner can maintain an optimal temperature, and shades or bulbs can correct the brightness, all in response to measures collected from various sensor types. Some of these actuators can also be connected to a weather based system, and use local weather data to adjust irrigation, heating and lightning schedules [2].

Typical SIS is programmed to collect data from specific devices, and react to a set of parameters in a predefined manner. Authors in [3], [4] and [5] implemented smart farming and irrigation systems using wireless sensor networks [6], to monitor moisture level, daylight intensity and other relevant information, and automatically plan irrigation cycles, water the farmland, or notify users with appropriate times to water. So far, similar works have indeed brought major benefits when compared to manual irrigation. However, some limitations have arisen. First, real life circumstances are sometimes unpredictable, then, user's needs are dynamic, and finally, the system itself, is prone to various evolutions (software and hardware). Therefore, static configuration of SIS becomes unsatisfactory.

The goal of this paper is to approach these limitations by designing the SIS as a dynamic constraint satisfaction problem, where the system is described as variables that abstract the various component of the system. And the user requirements are translated as constraints that restrict that value of these variables in specific domains. To achieve this goal, the Action Research methodology is adopted, specifically, the cyclical process [7]. The first step in the process is the *diagnosis.* It consists of studying the paradigm in order to identify its main limitations from a distinct point of view. Then an *action plan* is elaborated, from the various existing forms of action, to approach the problems identified. Following this step, the *action* planned is realized and implemented, and its consequences are studied and discussed. Finally, the main lessons learned are documented in the form of conclusions.

Following these steps, Section 2 investigates the problems related to current trends in designing SIS. Section 3 presents the action plan: an irrigation case is introduced in two scenarios, and the form of action endorsed in this paper is

described. Section 4 presents an implementation of the planned action and discusses the results. Section 5 presents the related work before conclusion in Section 6.

II. Related Work

For several years, smart irrigation systems have been tailored to fulfill a specific set of fixed requirements. Authors like [4] and [5], propose SIS that monitor and act according the established use cases defined at design time. However, the only form of adaptation that is managed in their work is limited to manual parameterization of decisive parameters [8] (When to irrigate? How long? What temperatures can be harmful, etc).

Designing smart systems in general and smart irrigation systems in particular, as self-adaptive systems, have attracted a lot of interest in the recent decade. Authors [9] like propose an SIS that works hand in hand with a simulation system in a closed controlling loop, where data is continuously fed to the simulator from the perception layers of the system, analyzed then sent back to control the actions. While authors in [10] adopted a cognitive approach, by correlating past actions and results to identify good data delivery paths and recommend intelligent adaptations.

The works of [11] and [12] propose self-adaptation mechanisms for the IoT in general, as they respectively built an intelligent gateway that learns users' behavior and interactions, and implemented a self-adaptive OS-based and reconfigurable embedded system according to objectives such as quality of service, performance, or power consumption.

While these works improve the self-adaptation capabilities of SIS systems, to the best of our knowledge, they focus on execution variability management, related to various changes in the context of the SIS, rather than deal with dynamic requirements, related to variability in time and space. The first refers to various possible configurations of the SIS for various situations, and the second, refers to possible evolutions of the SIS, in time.

III. Problem Investigation

A. Overview of Smart Irrigation Systems

Global food demand is exponentially increasing [13], while the need to conserve resources, like electricity or water, is becoming significant too [14]. Therefore, the interest in smart irrigation systems expands. Consequently, several research efforts have been made in this domain for the last decade, along with various solutions that have penetrated the market as well.

Authors in [15] for example use a GPS based remotely controlled robot to monitor real time field data, and perform irrigation tasks respectively, like watering, securing or fertilizing the field. Likewise, in [16], the irrigation system collects soil, moisture, temperature, humidity and light measures through sensors, and transfers them to a web server, which enables the corresponding actuators according to its preset optimal measures. Various other works tackle the problem in similar fashion, with slightly different technologies. For example, some use thermal imaging instead of conventional sensors to schedule irrigation cycles [17], and other authors focus on mapping the gap between communication technologies by combining heterogeneous devices [18].

Leader industrial solutions, like GreenIQ [19] or Rachio [20] share similar core concepts. As a matter of fact, while they may differ in specificities, the combination of their features includes the monitoring of soil conditions (humidity and tension), weather, evaporation rates, and the use of water by the plants to plan appropriate watering schedules. Therefore, as illustrated in Fig. 1, the main capabilities of SIS can be summarized in an operational MAPE-K loop [21]. According to the knowledge base, the monitor calls specific sensors for data measure, which are analyzed by comparing them to the optimums required. Then a planner determines the action to take, which can vary from planning irrigation cycles, to launching air conditioners or light bulbs, to doing nothing, when all measure comply.

From a technological point of view, as described in Fig. 2, context sensors and actuators usually operate with microcontroller(s), and are configured to transfer real time collected data at a specified frequency to a remote data collector and analyzer, through the Internet. A gateway interfaces devices that communicate with different communication protocols to the internet. A web, mobile or cloud-based collector, receives sensor data, and according to its configuration, requests the actuators to modify its context.

The cornerstone of any smart application is the configuration of its composing devices, and the configuration of the controllers (if any) that manage the overall operations. For example, the configuration of sensors dictates the frequency at which they send data to the collector, the optimal measure under or above which they could enable embedded alarms, or the battery level required to uphold a Wi-Fi connection. The configuration of an irrigator can specify the pressure of the water to administer as well as the duration if this process. The rotation can also be specified in the case of sprinklers or the speed of wheels in the case of center pivot irrigation systems. The configuration of an air conditioner can indicate the temperature to maintain in a greenhouse or the fan speed and direction. The configuration of the controller contains the parameters that trigger specific actions; like waking up a slave device, initiating a service, or transferring data between devices.

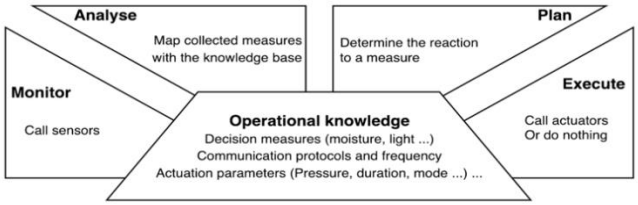

Fig. 1. Implementation of an Operational MAPE-K loop for SIS.

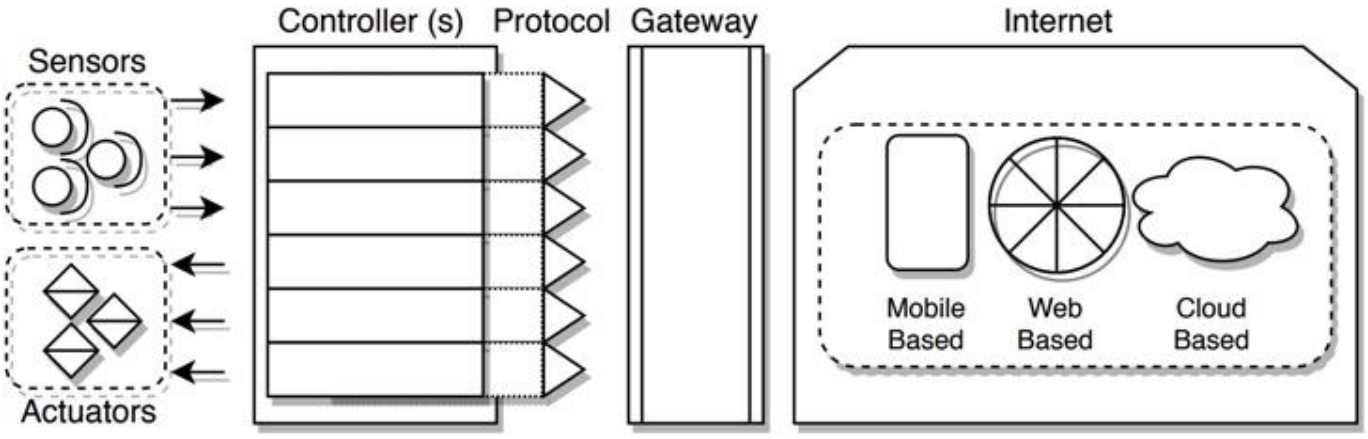

Fig. 2. Overview of a SIS Communication Loop.

While some SIS may offer dynamic parameterization options, to allow users to modify their optimal parameters, reset information about the plantation context, or be informed about the needs of their plants, the smart irrigation system host a static configuration. This configuration defines the pre-set mean of communication between various devices (e.g. the humidity sensors use a ZigBee based communication, the smart meter communicates through Wi-Fi, etc.), determines the devices responsible for achieving specific tasks (e.g. the sprinklers irrigate the field, the mains water provides water to the sprinkler), and may determine the reaction to specific changes in the environment (e.g. When the moisture of the soil is at a specific level, the system shall lunch the sprinkler).

B. Limitations of Static Configurations

A static configuration is defined during the development or implementation process, and remains unchanged over the lifetime of the SIS. However, the more these applications grow in size, complexity and users' expectations, the more maintenance and supervision efforts are required. Surely, the dynamic context of agricultural fields, the dynamic market of irrigation devices, and the various stakeholders that interact with a SIS require a more flexible and autonomous behavioral management, as illustrated in Fig. 3. These characteristics of SIS introduce the following challenges.

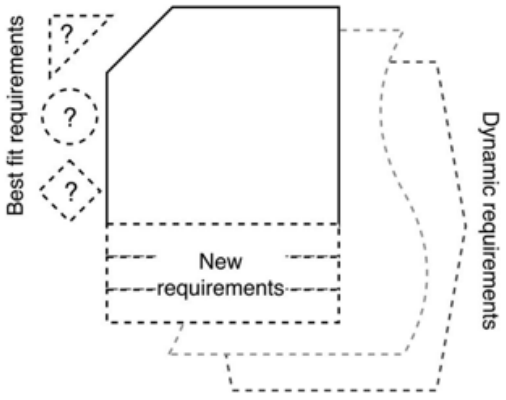

Fig. 3. Multiple Sources of Dynamic behaviour.

1) Best-fit configurations: The context of a SIS refers to everything that surrounds it, and has an impact on it. Some of these indicators influence the fulfillment of core requirements, while other provides information about the overall performance. The measure of humidity, temperature and brightness for example has an impact on the prosperity of the plant. Some other context indicators provide insight over other factors that are just as important to users, like the amount of water applied, the remaining battery level of devices, or the level of security established for communications. Depending on the collected context data, which provides an overview of the environment in which a system is running at real-time, *best fit requirements* specify the configurations that provide the best results, under the current circumstances.

2) Dynamic configurations: As time goes by, the final users and execution context of SIS evolve, in quality, and quantity. The first one refers to the evolutions/change of users' needs. For instance, when Maria sit up a Greenhouse to farm Bio Angelicas, being financially efficient was her first concern. As her business turned more profitable, the speed and quality of the products became more relevant. The configurations that are related to both aspects are therefore modified. The second one refers to the evolution of users themselves, thus their respective configurations. For instance, after a lucrative launch, Maria decided to sell her business. The new owners' approach and needs are slightly different from hers, which should be project on the configuration of the SIS too.

3) New configurations: Connected devices (e.g. Internet of Thing devices or IoT) are growing technical and scientific fields with great potential for innovation and development. Communication protocols, identification mechanisms, operating systems, and even new devices are entering the market with an unprecedented frequency. Installation, enrollment and maintenance cost can thus expand. New requirements describe the positioning of new components within the SIS, how they can interface and interact with previous components, and how they are supposed to operate.

IV. Action Planning

In order to tackle the problems introduced in the previous section, this paper proposes to design smart irrigation systems as self-adaptive systems (SAS) [22], that can automatically modify their behavior in the face of a changing context, to best answer a set of requirements. Thus, with respect to the MAPE-K loop framework in Fig. 4, the SIS monitors the context and the state of devices. The collected measures are mapped with the knowledge base, which englobes information about the application domain (e.g., sunflower cultivation), information about available resources (e.g., water), the distribution and characteristics of the actuators (e.g., water sprinklers), the context optimums (e.g., temperature, wind and humidity), and the user requirements. The compliance of the active configuration is determined, and the resulting action is planned. It could lead to a reconfiguration of the SIS, or to nothing when all measures comply. In order to achieve this goal, a case of an irrigation system is presented in order to illustrate the various problematics discussed above. Then, the core concepts used to design the SIS as a SAS re introduced and defined.

A. The Irrigation Case

To demonstrate the specificities in terms of requirements and illustrate the desired scenarios expected from the SIS, scenarios of an irrigation case are introduced in the following. The first scenario describes the requirements of a new company that wishes to construct a SIS that answers various needs of users, depending on the current context situation of the SIS. The second scenario presents the case of Maria, a new entrepreneur who decides to use GreenLife Solutions, with her own specific requirements.

1) Scenario 1: Best-fit requirements: GreenLife Solutions is a (fictive) company that wishes to build a SIS that monitors change in the environment, and maintains the required levels of moist, temperature and brightness, all while maintaining a good compromise between accuracy, and energy and water efficiency, to insure service durability. In their first prototype, they assume that a farm is rectangular, and needs up to 4 sprinklers to cover the field area. Along with the sprinklers, a drip line and a rooftop are installed to insure hybrid irrigation. The drip line consumes the least water, and the sprinklers are more accurate. The sprinklers can vary in rotation (360°, 240°, 180°, and 90°) and water pressure (20 to 40).

The irrigation devices are connected to two sources of water. The rainwater tank collects rain water, and the mains water is distributed by the local water provider. A water meter measures the level of water remaining in the tank and the water consumption from the mains source. The two sources are enabled alternatively. A pump is only required to be functional when the rainwater mode is enabled.

To collect information about the general state of the field, several sensors are to be installed on premise: Humidity sensors (HS) collect information about the humidity of the soil. Some humidity sensors have embedded alarms or lightbulbs, which can tinkle and twinkle. A HS can be slave (asleep until needed), or master (active). At least one master HS should be active in the fleet. A rain sensor (RS) is installed outside of the greenhouse. A light sensor (LS) detects the brightness inside the greenhouse. The rooftop can also alter the level of soil humidity and the brightness of the field. It can open partially to ventilate, open completely when raining, just enough to water the field, and it can close using the opaque roofing or the transparent one. These different configurations depend on the measures transmitted from the LS, the HS and the RS.

2) Scenario 2: Dynamic and new requirements: Maria owns a small farm in the countryside. She has been trying to plant Bio Angelica for years, but her work schedule does not allow her to move back and forth from the city to the farm. Angelica is a plant that grows better in partial shade, and needs specific attention in terms of irrigation. Therefore, to help Maria supervise the process remotely, the GreenLife solution was recommended to her.

From Maria's perspective, the SIS must activate the sprinklers as long as the water consumption from the smart meter is below the maximum allowed. The first two sprinklers have a 180° rotation, while the second two have a 360° rotation. They all pump water in a 30 psi. When the consumption of water goes higher than the maximum, the SIS switches to the dripline. The rooftop is activated for irrigation when the RS detects rain. The rooftop uses the opaque roofing when the brightness in the field is above the normal measure, and switches to the transparent roofing when the brightness is lower.

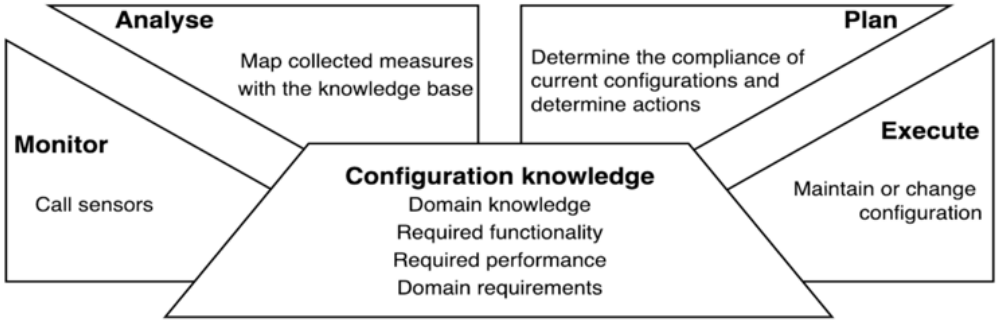

Fig. 4. Implementation of the SIS in the MAPE-K loop Framework.

By default, the water is distributed from the rainwater, as long as the water level in the tank is normal, and the power is on. If one of the two conditions is not fulfilled, the switch lever moves to the Mains water. The rain sensor broadcast information about rain instantly at summertime and with a time span during winter, due to air humidity. To avoid disturbance during the night time, all alarms are deactivated. In the morning, the bulbs are deactivated. All displays and alarms are disabled when there is no human presence detected around the field. When the electricity consumption is normal, all HS are in the master mode. This number is minimized when the electricity consumption becomes higher.

After the period of a year, Maria was not fully satisfied of the outcome of the greenhouse. She decided to worry less about the water and energy efficiency, and concentrate more on accurate means. Her new specifications were the following: "The sprinklers are the only mean of irrigation. Respectively, the rotation and pressure of the first two sprinklers is 240° and 30 psi and of the second two is 360° and 40spsi. Humidity sensors are all on master mode. The fertilizer shall be connected to the sprinklers to fortify the plants. The rooftop is always on opaque mode in the mornings, and is transparent in the evenings and at night.

B. A Constraint-Based Smart Irrigation System

1) Constraint programming: Constraint programming is a declarative paradigm used to solve real world problems, and can be used as a formalism to specify systems and processes, described in the form of variables. Instead of defining an algorithm that describes the instructions needed to solve a specific problem, a constraint program defines the properties that the solution is required to have, and delegates the decision-making tasks to a solver. In this approach, the program is called a Constraint Satisfaction Problem (CSP), and is defined in terms of variables and dependencies that constraint the valuations of these variables in their respective domains.

The SIS can be modeled as a CSP, where variables are abstractions of all the elements of the system, as illustrated in Fig. 5. They can represent a device, a component or a function of the system or its environment. The constraints defined over variables translate the user's requirements. Thereupon, they can define a restriction on the value of a parameter, determine whether or not a component should be enabled, or communicate a preference or a choice of the user. Eventually, the solution derived from the SIS as a CSP specifies a configuration of the system, which fulfils the requirements of the users in an active context.

2) Dynamic constraint satisfaction problems: Static constraint satisfaction problems can be proven efficient for the specification of systems such as SIS. However, as discussed above, these systems undergo continuous change, even after their initial specification. Reasoning about such dynamic environments is beyond CSP, as they stipulate that the set of variables and constraints is known and fixed beforehand. Dynamic Constraint Satisfaction Problems (DCSP) provide the necessary mechanisms to progressively analyze different sets of variables/constraints, for the same problem. In this paper, the DSCP is viewed as a sequence of CSP, where constraints are added/removed from the problem incrementally [23].

In the case of SIS, dynamic requirements are translated as new constraints that dynamically modify the problem. Furthermore, as the elements composing the SIS are prone to evolution, their abstractions as variables may or may not be actively part of a version of the problem.

3) Flexible constraints: For the most part, typical CSPs deal with hard constraint that shall be satisfied to solve the overall problem. However, real world problems are more flexible in nature. therefore, flexible constraints were introduced to allow the specification of problems that are over-constrained. With this approach, even when some of the flexible constraints cannot be satisfied, a useful solution can still be derived [24].

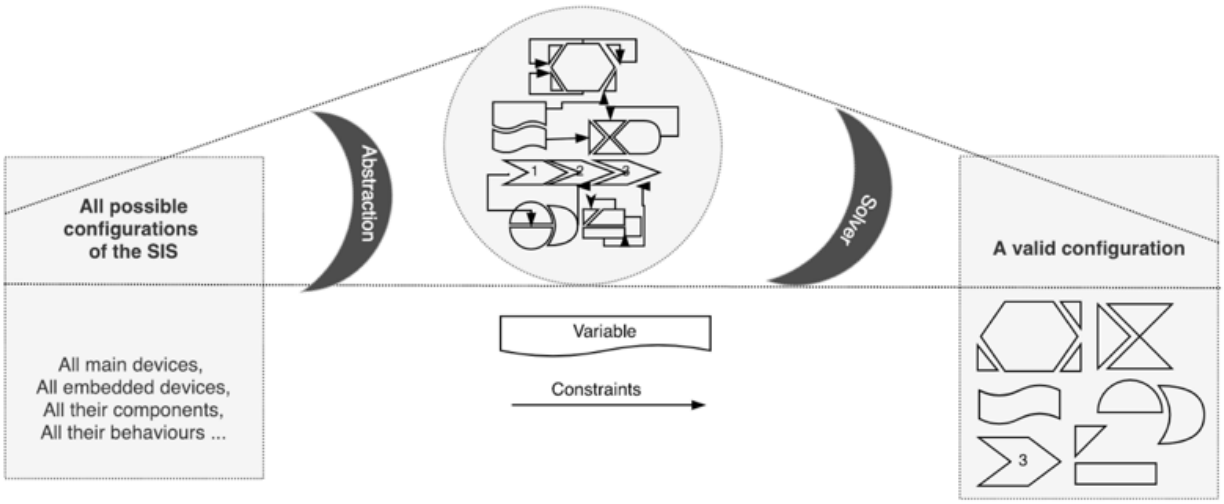

Fig. 5. Representation of a SIS as a CSP.

V. Action and Discussion

The specification of the SIS, as described by GreenLife Solutions, then by Maria and her partner are implemented in Minizinc[1], respectively in the form of CSP and DCSP.

In this section, each scenario is described in the form of a constraints problem; a configuration is generated, and is analyzed to verify its compliance with the needed functionality and performance.

A. Best-Fit Requirements as a CSP

1) Representation: The scenario described in (1)) can be designed as a CSP. The various components of the SIS are abstracted into variables, and the rules that govern the nature of their relationship are defined as constraints over these variables. This approach was first proposed by [25] and [26] and applied to the IoT in cases like [27].

First, the elements of the SIS, along with the functional and nonfunctional requirements they are supposed to fulfill, are declared as variables. Functional requirements (FR) can be satisfied or not. Thus, the domain in which they are solved is Boolean. Nonfunctional requirements (NFR) are of a more relaxed nature. They can be defined over a wider domain. This helps define different priorities to the different NFRs depending on user preferences and expectations.

Finally, components that realize completely the FR, or partially the NFR, are declared as Boolean or numeric variables; the variables that can be selected or omitted in a configuration are defined over a Boolean domain. Similarly, elements that define parameters that are instantiated depending on the runtime state are defined in their respective domains.

```
%Declaration of the functional requirements
var 0..1: Maintain_Plants;
var 0..1: Irrigate;
var 0..1: Monitor;
%Declaration of nonfunctional requirements
var int: EnergyEfficiency ;
var int: WaterEfficiency ;
var 0..4: HSAccuracy ;
var 0..4: HSEnergyEffciency; …
% Declaration of the  SIS components
var bool: Dripline;
var bool: Sprinkler1;
var bool: Sprinkler2; …
%Declaration of integer variables
var 20..60: Pressure1;
var 90..360: Rotation1; …
```

According to the irrigation and monitoring rules defined in Section (1), the system elements are connected, thus constrained are presented in the following code snippet.

```
%FR constraints
Cst1_1 : constraint Maintain_Plants = 1;
Cst1_2 : constraint Maintain_Plants * 2 = Irrigate + Monitor;
%Examples of irrigation constraints
Cst1_5 : constraint Irrigate  >= FertilizerUnit; % A Fertilizer unit is optional
Cst1_11 : constraint Irrigate>=Dripline /\ Irrigate>=Rooftop /\ Irrigate*4>=Sprinkler1+Sprinkler2+Sprinkler3+Sprinkler4 /\ ((Dripline + Rooftop +(Sprinkler1+Sprinkler2+Sprinkler3+Sprinkler4))=1 \/ (Dripline + Rooftop + (Sprinkler1+Sprinkler2+Sprinkler3+ Sprinkler4) =4)) /\ Dripline * Rooftop * (Sprinkler1+ Sprinkler2+ Sprinkler3+ Sprinkler4)=0;  %Mutual exclusion between sprinklers, Dripline and Rooftop
Cst1_15 : constraint Sprinkler1 >= 1 <-> (Rotation1 >= 1); %if the sprinklers are selected, the pressure shall be instantiated as well
%Examples of monitoring constraints
Cst1_27 : constraint Monitor = RS; % The rain sensor is mandatory
Cst1_29 : constraint HS1 >= Master1 /\ HS1 >= Slave1 /\ HS1 = Master1 + Slave1 ; %A humidity sensor can either be Master or slave
```

The impact that every component of the SIS has on its performance is defined by claims, which are maximized according to the preferences set by the users, towards an appropriate solution.

```
%Example of the impact of components on performance
Cst1_38 : constraint C1 > 0 <-> ((Sprinkler1 + Sprinkler2 + Sprinkler3 + Sprinkler4 > 0) -> IrrEnergyEfficiency <= 2) /\ (Dripline > 0 -> IrrEnergyEfficiency = 3) /\ (Rooftop >= 0 -> IrrEnergyEfficiency >= 4); %The sprinklers use most of the water, then the dripline, and finally the rooftop is the least consuming
%Maximization function
Cst1_50 : constraint SIS_Config = Energy_Preference * EnergyEfficiency+ Accuracy_Preference * Accuracy + Water_Preference * WaterEfficiency;
solve maximize (SIS_Config);
```

2) Discussion: All the constraints defined above compose the CSP. Once run by the solver, a configuration of the SIS is supplied. Chart 1 illustrates two configurations derived from the same CSP, each corresponding to the preferences of Maria, then Sophia, her partner. Maria needs the system to run in an energy efficient (**EE**) manner, while Sophia requires accuracy (**A**). Theses preferences can be set respectively by instantiating the parameters *Accuracy_Preference; Energy_Preference and Water_Preference*, with their respective weights. Fig. 6 shows (in red), the configuration generated when accuracy (A) has the biggest weight. Similarly, the charts delineate (in blue) an energy efficient (EE) configuration.

[1] https://www.minizinc.org/

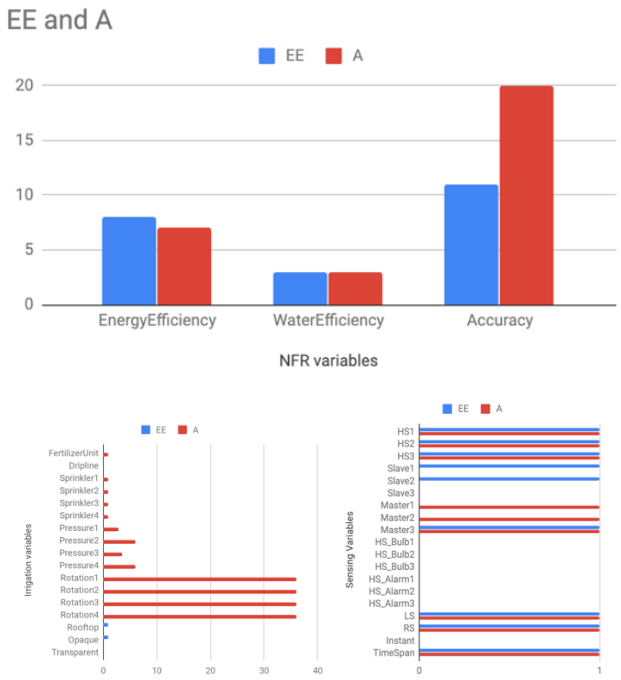

Fig. 6. The Configuration of the SIS (Scenario 1).

As expressed by the constraints presented below, the configurations mainly differ in the use of Sprinklers and rooftop (Table I: Irrigation variables). The first being energy consuming but accurate as it receives data from the sensors and reacts accordingly. Then the second being energy efficient, but inaccurate as irrigation depends on an unpredicted element with is rainfall. Another variable between both configurations is the number and state of humidity sensors (Table I: sensing variables). Indeed, selecting multiple HS increases the accuracy of the collected data. The more master HS there are, the more data is representative of the field's actual state. Similarly, the less active HS there are, and the more they are in the Slave state; the less energy is consumed, at the expense of accuracy. Other invariable are similar as they do not impact either accuracy not energy efficiency according to the CSP.

B. Dynamic and New Requirements as a DCSP

1) Representation: The way Maria intends to use the SIS is tightly related to fluctuations in the context. Thus, to maintain satisfying performance under various conditions, she specifies different requirements to achieve the same goal. Therefore, the constraints introduced to the CSP differ, depending on current context.

The context can also be defined in constraint programming as a set of variables, which are abstractions over a part of the system's environment that has an impact on the activity or quality of the SIS. They can be monitored at runtime by sensing or by reporting, and are thus dynamic. Context elements that are valuable to Maria's case are declared below.

For each context situation (an instantiation of context variables to specific values), a set of requirements shall be fulfilled (a set of constraints shall be validated). Vice versa, as a new context situation occurs, requirements that were once mandatory become obsolete (thus, the previous set of constraints becomes irrelevant, and the new one shall be validated instead).

```
%Declaration of context variables
0..1: Smartphone_Availability;
0..1: Power_failure;
0..1: Rain;
int: Light;
int: MaxLight;
int: TankCapacity;
0..TankCapacity: TankLevel;
int:MinTankWater;
int: MainsWaterConsumption;
int: MaxMainsConsumption;
1..12: Month;
1..31: DayOfMonth;
00..24:Time;
1..10: int
```

Adding requirements to an existing SIS is a two steps process. The first one lies in defining the new constraints (representative of the new requirements), and the second process consists of relaxing unrefined constraint, as to not contradict with new specifications. This is presented in the following, in the form of Reified and Flexible constraint.

a) Reified constraints: The reification of a constraint *c* is the association of a Boolean variable *B* to a constraint *C*. When *B* is true/false, the reified constraint shall be satisfied/unsatisfied, respectively. Similarly, when C is satisfied/unsatisfied, B should be set to true/false, respectively. In some constraints, a simple implication is used instead of a full reification, to avoid inconsistency with previous constraints.

```
%Constraints on global events
Cst2_1 : constraint Year<=2 <-> GlobalRC1;
Cst2_2 : constraint Year>2  <-> GlobalRC2;
```

The requirements expressed during the first year, as described in (2)), are specified in the code bellow. The occurrence of an event (eg: rain), sets the value of the related reified constraint to *True* (eg: RC10=True), therefore enforcing the constraints reified by RC10, (e.g. Rooftop= 1;). Similarly, all the other requirements that shall be fulfilled under specific circumstances are translated into constraints that shall be satisfied when the related reified constraints are true.

```
%----------------First year requirements
%Examples of constraints that express Events -- First Year
Cst2_10 : constraint (GlobalRC1 /\ Month >=5 /\ Month <10) <-> RC2_3; %Summer
Cst2_11 : constraint (GlobalRC1 /\ Smartphone_Availability = 1 )<-> RC3; %Humain presence
Cst2_15 : constraint (GlobalRC1 /\ Power_failure = 1) <-> RC6; %No electricity
Cst2_17 : constraint (GlobalRC1 /\ Light <= MaxLight) <-> RC8; %Normal bright
Cst2_19 : constraint (GlobalRC1 /\ Rain = 1) <-> RC10; %Raining
Cst2_20 : constraint (GlobalRC1 /\ (TankLevel >= MinTankWater /\ Power_failure = 0)) <-> RC11; %Water provided from Rainwater
Cst2_22 : constraint (GlobalRC1 /\ (MainsWaterConsumption >= MaxMainsConsumption) /\ RC10=0)<-> RC13; %Water consumption is Hight
%Examples of reified constraints and their respective actions -- first year
Cst2_39 : constraint RC2_3 -> TimeSpan=1;
Cst2_40 : constraint RC3 -> Treshold_Alarm >= 0 /\ HS_Alarm1 >= 0 /\ HS_Alarm2 >= 0 /\ HS_Alarm3 >= 0 /\ HS_Bulb1 >= 0 /\ HS_Bulb2 >= 0 /\ HS_Bulb3 >= 0;
Cst2_43 : constraint RC6 -> (Master1 + Master2 + Master3) <=2 /\ RC4=1 ;
Cst2_47 : constraint RC8 -> Transparent = 1;
Cst2_49 : constraint RC10 -> Rooftop= 1;
Cst2_50 : constraint RC11 -> Rainwater=1;
```

Similarly, the expectations of Maria for the second year are expressed as a new set of requirements, translated into new constraints. Therefore, a new CSP is to be solved, since the previous constraints are no longer relevant.

```
%----------------Second year requirements
%Examples of constraints that express Events-- Second year
Cst2_25 : constraint GlobalRC2 /\ (Time >=10 /\ Time <16) <-> RC17;
Cst2_27 : constraint GlobalRC2 <-> RC14;
Cst2_31 : constraint GlobalRC2 <-> RC20;
%Examples of reified constraints and their respective actions -- Second year
Cst2_53 : constraint RC14 -> Sprinkler1+ Sprinkler2 + Sprinkler3 + Sprinkler4=4 /\ Pressure1=30 /\ Pressure2=30 /\ Pressure3=40 /\ Pressure4=40 /\ Rotation1=240 /\ Rotation2=240 /\ Rotation3=360 /\ Rotation4=360;
Cst2_56 : constraint RC17 -> Opaque = 1;
Cst2_59 : constraint RC20 -> RS + LS + Instant + TimeSpan = 0;
```

b) Flexible constraints: As the SIS evolves, the constraints that were once mandatory may become irrelevant or reduced in priority. Therefore, constraints that once defined a static structure of the SIS can be subject to change. For example, a component that was mandatory (Rain sensor) may become undermined (RS=0). The irrigation and monitoring components, presented in 4.1. can be transformed into flexible constraints. The goal is to maximize their satisfiability rather than solve them. If no contradictory constraint is introduced in time, the problem is likely to be satisfied completely. However, if it is the case, some of the constraints are allowed to remain unsatisfied, without inconsistency warnings. Constraints (Cst1_10, Cst1_26, Cst1_27) are not satisfied in the light of new requirements. However, since they are now flexible, their unsatisfiability does not generate inconsistencies.

```
%----------------Example of flexed requirements
Cst2_8 : constraint Flex6 <-> Rooftop >= Opaque /\ Rooftop >= Transparent /\ Rooftop >= Opaque + Transparent /\ Opaque + Transparent <= Rooftop;
Cst2_22 : constraint Flex19 <-> Monitor = LS;
Cst2_25 : constraint Flex20 <-> Monitor = RS;
```

C. Discussion

According to these constraints, the configurations of the SIS, during the *first*, then the *second* year, which correspond to the context variables presented in Table I, are respectively represented by *Red* and *Blue*, in the Fig. 7.

The configurations generated indeed in accordance with Maria's requirements. For the first year, if it is raining (T1:rain=1), then the rooftop shall be selected (T2: Rooftop = 1). Other irrigation means are momentary disabled (T2: Dripline=0 & Sprinklers=0), until another configuration specifies otherwise. Human presence is detected around the field (T1:Smartphone_Availability=1), therefore, display devices are enabled including humidity sensor' alarms and bulbs, and the tank's threshold alarm (T2: HS_Bulb(1,2,3)=1, HS_Alarm(1,2,3)=1, & Treshold_Alarm=1). However, since it's the morning (Time=15), bulbs are inefficient (HS_Bulb(1,2,3)=0), as they consume energy without playing a crucial role, therefore, they are disabled (T2:HS_Bulb(1,2,3)=0). As the energy state is normal (T1: Power_Failure=0), all humidity sensors are active (HS(1,2,3)=1), and are on master mode to maximize data precision. The brightness level is higher than required for a healthy plant, therefore, the opaque shades are enabled (T2: Opaque=1). The level of water in the tank is above the minimum required, therefore, it will be responsible for providing irrigation water (T2:Rainwater=1), and will thus require a working pump (Rw_Pump=1) as well. Finally, as it is winter time (Month=11), and since air humidity is high, the RS is likely to mistake faug with rain, thus, the decision about rain is made with a timespan (T2:Timespan=1) to insure the righteousness if the information. During the second year, irrigation shall only be supplied using sprinklers (Sprinkler(1,2, 3, 4)=1), with specific ratios. All humidity sensors are on master mode. And all display devices are disabled.

TABLE. I. INSTANCES OF CONTEXT VARIABLES

Power Failure	Rain	Light	Max Light	Tank Capacity	Tank Level
0	1	51509	46332	20000	7681
MinTank Water	**Mains Water Consumption**	**MaxMains Consumption**	**Smartphone Availability**	**Month / DayOfMonth**	**Time**
998	220977	200000	1	11/ 2	15

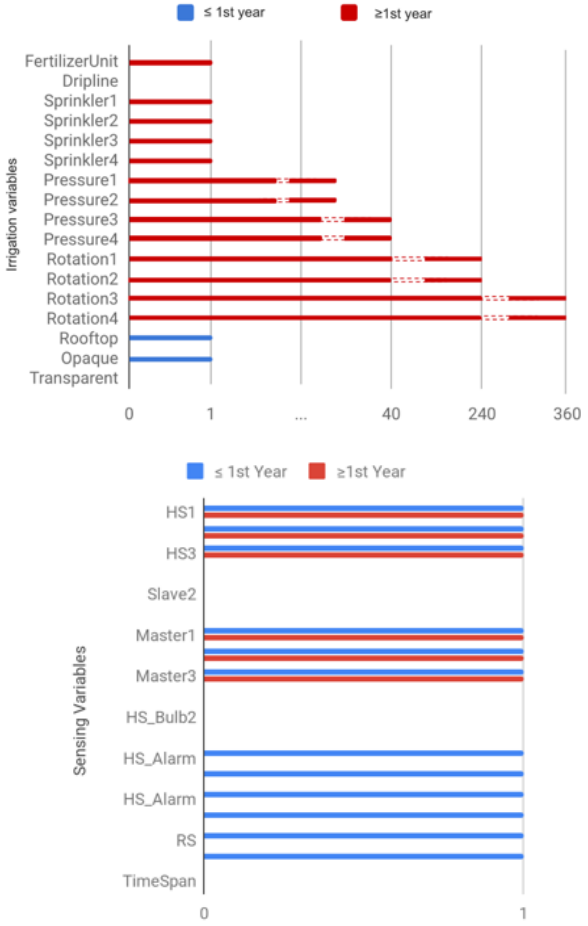

Fig. 7. The Configuration of the SIS (Scenario 2).

VI. CONCLUSION AND PERSPECTIVES

The investigation of the domain of smart irrigation systems shows that contemporary ecological challenges on the one hand, and society's constant need for sophisticated technology on the other hand are big factors that impact the state of the art of the internet of things in general, and smart irrigation systems in particular. Consequently, the generation of SIS, that simply consisted of reporting on environmental data, and reacting or planning irrigation cycles, is on the verge of becoming obsolete. This is mainly a result of user's requirements that are perpetually changing, and technology that is constantly evolving.

The action taken in this paper consists of representing SIS's components as variables, and their relations as constraints, forming a dynamic constraint satisfaction problem. Through a solver, this paradigm finds a solution that (best) fits the (dynamic) requirements of users. Therefore, instead of enrolling a SIS that has a set configuration, designing it as a dynamic and flexible constraint satisfaction problem allows the specification of these dynamic requirements, and therefore, the generation of configurations that fully or partially satisfy them, on the go. Thanks to sensors and various types of data that can be provided to irrigation actuators, SIS can now be designed to accompany dynamic environments, but also, dynamic requirements in time and place.

The snippets of constraint code introduced above are manually written in a Minizinc editor. Being that as it may, it is a fastidious, time consuming and illegible way of documenting constraints. Implementing the main concepts to build such programs proves essential. Therefore, as a perspective, a language that allows the specification of dynamic requirements in fleets of connected devices, and enables the generation of configurations that comply with real time contexts proves substantial.

ACKNOWLEDGMENTS

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Vietnamese Speech Command Recognition using Recurrent Neural Networks

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***Abstract*—Voice control is an important function in many mobile devices, in a smart home, especially in providing people with disabilities a convenient way to communicate with the device. Despite many studies on this problem in the world, there has not been a formal study for the Vietnamese language. In addition, many studies did not offer a solution that can be expanded easily in the future. During this study, a dataset of Vietnamese speech commands is labeled and organized to be shared with community of general language research and Vietnamese language study in particular. This paper provides a speech collection and processing software. This study also designs and evaluates Recurrent Neural Networks to apply it to the data collected. The average recognition accuracy on the set of 15 commands for controlling smart home devices is 98.19%.**

Keywords*—Vietnamese speech command; voice control; Recurrent Neural Networks

I. Introduction

Interaction and control of household devices is a fast trend, evident in the exponentially growing number of smart-homes. According to Statista, the number of active households worldwide is 67.4 million in 2019. And this number is expected to amount to 111.2 million by 2023 [1]. The goal of research in this field is to improve the interaction so that it is faster, more convenient and more flexible. Therefore, speech recognition and natural language processing with the support of Artificial Intelligence seems to be the inevitable route.

In "Binary Neural Networks for Classification of Voice Commands from Throat Microphone" [2], the authors uses binary classifiers and Neural Networks (NNs), together with a perceptual linear prediction method for feature extraction to increase the classification rate of voice commands captured using a throat microphone, comparing this method with a single NN. They create a dataset of 150 people (men and women). All the voice samples are captured in Brazilian Portuguese, with the digits "0" through "9" and the words "Ok" and "Cancel". The results show that a throat microphone is robust in noisy environment, achieving a 95.4% hit rate in a speech recognition system with multiple NNs using the one-against-all approach, while a simple NN could only reach 91.88%.

In "Design and Implementation of Voice Command Using MFCC and HMMs Method" [3], feature extraction methods used are the Mel frequency cepstral coefficient (MFCC). Early stages of MFCC split the input signal amplitude values into frames which are then processed by the mel-filter bank. The results of feature extraction are made into a codebook, which is then used as an input symbol on a Hidden Markov Model (HMM) to form a model for every word. During testing, the characteristics of the test signal that has been quantized are then matched with the model created in the previous step. The final system can recognize spoken words with an average accuracy of 93.89% in a noiseless environment, and 58.1% in noisy environments.

In recent years, Deep Learning have become one of the common approaches used in speech recognition (SR), with SR systems based on Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) achieving great results in various SR benchmarks [4,5,6].

In "Speech Recognition Based on Convolutional Neural Networks" [7], Du Guiming et al. propose to use the CNN principles in frequency domain to normalize acoustic variations for speech recognition. Here the researchers use a 5-layer CNN. It can achieve isolated word recognition by training the CNN.

In "End-to-End Speech Command Recognition with Capsule Network" [8], Jaesung Bae, Dae-Shik Kim realize that CNNs are capable of capturing the local features effectively. They can be used for tasks which have relatively short-term dependencies, such as keyword spotting or phoneme-level sequence recognition. However, one limitation of CNNs is that, with maxpooling, they do not consider the pose relationship between low-level features. Motivated by this, the researchers use a capsule network to capture the spatial relationship and pose information of speech spectrogram features in both the frequency and time axes. Compared to CNN models, the capsule-network-based systems achieved much better results from both clean and noisy data.

The above studies have shown that deep learning is the most effective solution at the present time to improve accuracy. It also seems that the end result can minimize the dependence of the problem on a specific language when the learning data is big enough. The gap here is to evaluate and customize a network architecture that matches a particular language database. In addition, the solution should be easily expanded on in the future.

The main contribution of this paper is to develop a method for recognizing Vietnamese speech commands based on deep learning technologies. A Vietnamese command dataset that includes 15 commonly used commands for smart homes (Table I) has been labeled and is publicly available for the research community on GitHub [9]. In addition, the source code for the data collection software for both Android and iOS is also made available on Github. Users can easily contribute

data via software, and it can also be easily modified for other languages. New commands can also be added in the future.

TABLE I. LIST OF SPEECH COMMANDS

No	In Vietnamese	equivalent English meaning
1	Đô rê mon	Doraemon (Trigger word)
2	Bật đèn	Turn on light
3	Tắt đèn	Turn off light
4	Bật điều hòa	Turn on air conditioner
5	Tắt điều hòa	Turn off air conditioner
6	Bật quạt	Turn on fan
7	Tắt quạt	Turn off fan
8	Bật tivi	Turn on TV
9	Tắt tivi	Turn off TV
10	Mở cửa	Open door
11	Đóng cửa	Close door
12	Khóa cửa	Lock door
13	Mở cổng	Open gate
14	Đóng cổng	Close gate
15	Khóa cổng	Lock gate

The remainder of the paper is organized as follows. Section 2 describes the data collection process. The data processing step is presented in Section 3. Section 4 provides the selection and evaluation of deep machine learning architectures based on RNN. Then, Section 5 analyzes the application results of the selected architecture for the Vietnamese command dataset. Finally, conclusions are made in Section 6.

II. DATA COLLECTION AND PROCESSING

A. Data Collection Software

In order to ensure the robustness and high accuracy of the identification process, the collected data needs to meet a number of requirements such as diversity in age, gender and region. In addition, the software needs to be easy to use. The software interface should be friendly and easy to understand.

The "*SpeechCollection*" application is written for both Android and iOS to be accessible to all users. Volunteers who wish to participate in data collection can download the software via Google's Play Store or Apple's App Store. Each speech command is recorded at the sampling frequency of 8Khz. The results are shared through Google cloud. Data will then be reviewed by the research team for quality and information, and the results will be stored in the final data directory. The main functions of the application are described in Fig. 1. An activity diagram is shown in Fig. 2. Fig. 3 shows the interface of the application in the sequence that a participant contributes data.

B. Data Organization

Each participant in the data collection will contribute a directory tree. The outermost folder is Name_Email. Next are the age_gender_province_timestamp. The bottom is the subdirectories corresponding to the words in the list of 15 desired words.

All data will be compressed before being sent to Google Cloud to reduce upload time. The average upload time is about 5s with a 3G or Wi-Fi connection under normal conditions.

The data collected after 1 month of the research contains voices of 293 people with fairly balanced ratios between men and women, age groups (younger than 18, between 18 and 30, between 30 and 40, older than 40) and regions (Northern, Central and Southern).

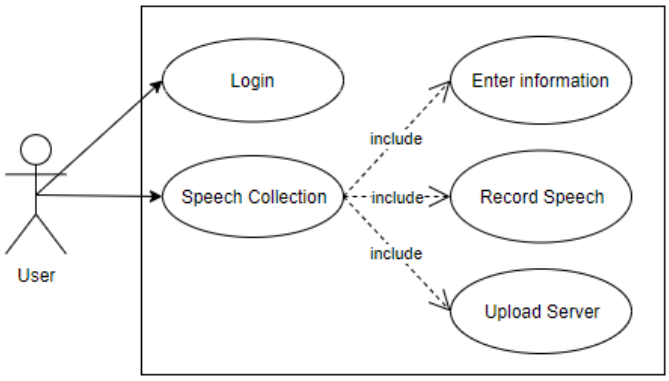


Fig. 1. Use Case Diagram.

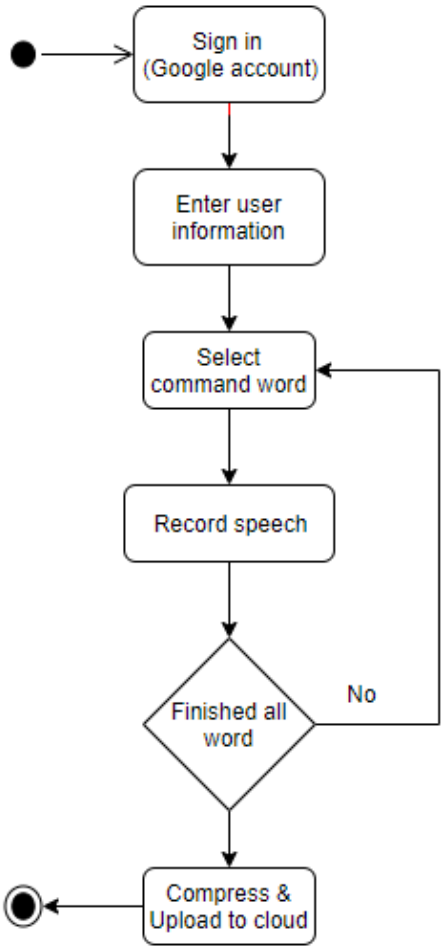


Fig. 2. Activity Diagram.

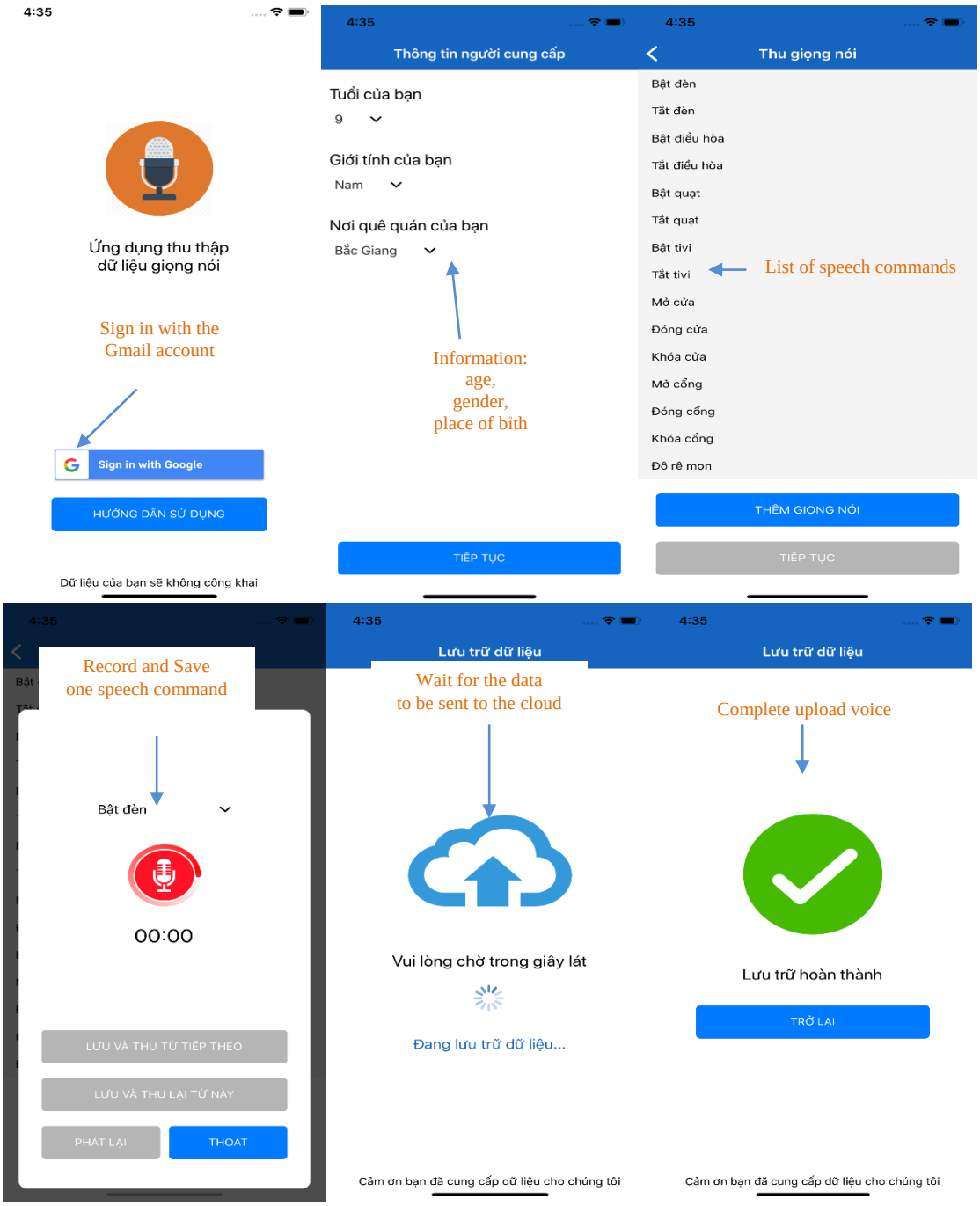


Fig. 3. Screen Flow of "SpeechCollection" Application.

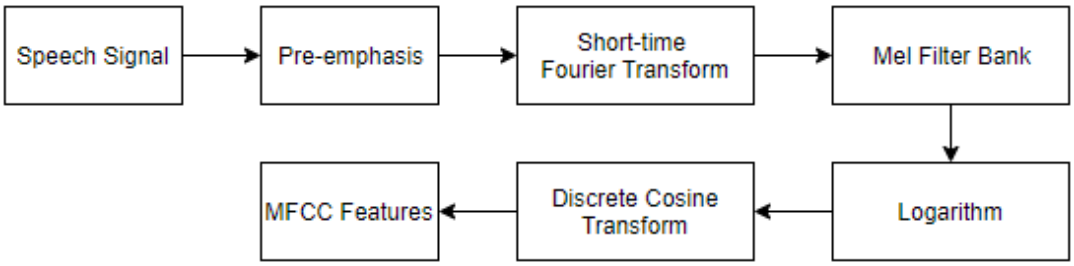


Fig. 4. MFCCs Extraction Algorithm.

C. Data Processing

1) Data filtering and trimming: The raw data contributed by user might contains a lot of silences and noises. So, the first step to filte and trim the silences at the beginning and the end [10]. Because the frequency range of speech signals is from 300Hz to 3400 Hz, a simple linear bandpass filter is used to eliminate out-of-band noise. Filtered data then is trimmed to remove silences. The data is then divided into continuous frames with a length of 0.05 seconds each. The Short Time Energy (STE) on each frame is calculated and compared to the average STE value. Frames with STE greater than the average value are retained whiel the rest is treated as the silence and removed.

2) Data augmentation: Data after trimming has different lengths, and the maximum length is less than 1.5 seconds. However, the data needs to be standardized to the same duration to make it easier to extract features used for machine learning. In addition, the data should be similar despite being collected in different environments. So, in this step the data needs to be augmented, and lengthen to a standard duration.

For background noises, audio recordings were conducted in 10 different environments (library, school, kitchen, room, road, etc.). Each recording has the same length of 2 seconds. These data are used then as background sounds, overlaid over the trimmed audio in the previous step at random. After data augmentation, we obtain the final dataset of approximately 3200 data samples for each speech command.

3) Feature extraction: Each 2-second sample of data is a time-series signal, from which features are extracted to provide a deep learning network input. The feature extraction algorithm is described as shown in Fig. 4 [10].

The first step is to apply a pre-emphasis filter on the signal to amplify the high frequencies.

The second step, a STFT transform is used because spectral analysis show that different timbres in speech signals corresponds to different energy distribution over the frequencies. The speech signal is segmented into frames of 25ms with an overlap of 15ms for each of the frame. The winstep is 10ms (25ms -15ms) and NFFT = 512, therefore each 2-second audio will be split into 200 frames, each FFT frame has NFFT / 2 + 1 = 257 frequency bins. The spectrogram has shape = (257, 200).

The third step utilizes the mel scale, a psychoacoustic scale of pitches of sounds. It is a scale that more closely represent what the human ears capture. The transfer formula is rather simple:

$$m = 2595 * \log_{10}\left(1 + \frac{f}{700}\right) \quad (1)$$

Each spectrum frame is multiplied with the corresponding filter, then the results are added to get a filter bank response. So, with M filters, this results in M filter bank energy vectors on a frame. In this study, the value of M selected is 13.

Finally, the logarithmic spectrum of the mel scale is converted into the time scale by using the DCT. A cepstrum is the result of taking the inverse transform of the logarithm of the estimated spectrum of a signal. Apply DCT on the 13 Log Filterbank Energies x(n) to have 13 Mel-scale cepstral coefficients. For each frame of spectrogram, there are 13 Mel-scale cepstral coefficients, so MFCC features of a 2-second sample of speech signal is a two-dimensional array with a shape of (13, 200).

III. Neural Network Architecture

A. Proposed Architecture

For Deep Networks, the focus is mostly on the two major architectures: CNNs for image modeling and Long Short-Term Memory (LSTM) Networks (Recurrent Networks) for sequence modeling.

The goal of a CNN is to learn higher-order features in the data via convolutions [11]. They are well suited to object recognition of faces, individuals, street signs, platypuses, and many other aspects of visual data. However, in [7,8], the authors have stated that one limitation of CNNs is that, with maxpooling, they do not consider the pose relationship between low-level features.

Recurrent Neural Networks are in the family of feed-forward neural networks [11]. They are different from other feed-forward networks in their ability to send information over time-steps. Recurrent Neural Networks take each vector from a sequence of input vectors and model them one at a time. This allows the network to retain state while modeling each input vector across the window of input vectors. Modeling the time dimension is a hallmark of Recurrent Neural Networks. Recurrent Neural Networks can have loops in the connections. This allows them to model temporal behavior and gain accuracy in domains such as time-series, language, audio, and text.

Long Short-Term Memory (LSTM) is a type of RNN architecture that addresses the vanishing/exploding gradient problem and allows learning of long-term dependencies [11]. A common LSTM unit is composed of a cell, an input gate, an output gate and a forget gate. The cell remembers values over arbitrary time intervals and the three gates regulate the flow of information into and out of the cell. LSTM networks are well-suited to classifying, processing and making predictions based on time series data, since there can be lags of unknown duration between important events in a time series. Therefore, we use this LSTM architecture for training models in Automatic speech command recognition.

When using unidirectional RNNs as generative models, it is straightforward to draw samples from the model in sequential order. However, inference is not trivial in smoothing tasks, where we want to evaluate probabilities for missing values in the middle of a time series. In bidirectional RNNs, data processed in both directions processed with two separate hidden layers, which are then fed forward into the same output layer. Therefore, this can better exploit context in both directions. Hence bidirectional LSTMs usually perform better than unidirectional ones in speech recognition.

In this study, we implement and evaluate the performance of two models, unidirectional RNNs and bidirectional RNN for automatic speech command recognition.

B. Implementation of the Neural Network

The Keras interface was used to implement all neural networks on top of a Tensorflow backend. The Python library python_speech_feature is used to calculate MFCC for feature extraction.

1) Input of neural network: MFCC features are fed into the model. In each frame of audio, 13 features are obtained after the extraction algorithm. Each frame is added to the array in time order. Finally, the entire array of data after the process is added in the batch to train the model.

2) Models: To make sure the model works, it is first trained with a available dataset, the Google Speech Dataset V1 [12]. The Google Speech dataset V1 has 35 commands with audio files of 1 second in length. So, for each audio file, MFCC features is a two-dimensional array with a shape of (13, 100).

In the first model, unidirectional RNNs, speech command recognition depends on the data series over time, so on the top level of model, two LSTM layers are used to extract special features with long-term dependent of audio data. Then, the weighted average of the LSTM output is fed into 3 fully connected layers in the end for classification (Fig. 5).

In the second model, bidirectional RNNs, two Bidirectional LSTM (BiLSTM) are used. BiLSTM contains two single LSTM networks that are used simultaneously and independently to model the input chain in two directions: from left to right (forward LSTM) and from right to left (backward LSTM). Finally, the weighted average of the LSTM output is fed into 3 fully connected layers for classification (Fig. 6).

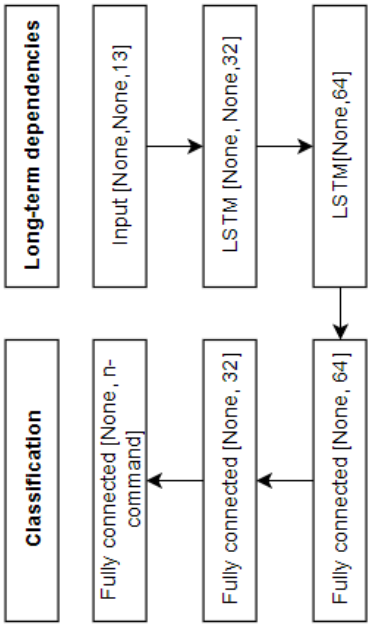


Fig. 5. LSTM Model for Speech Command Recognition.

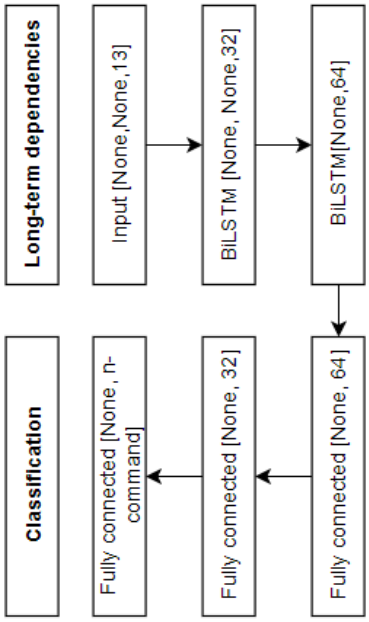


Fig. 6. BiLSTM Model for Speech Command Recognition.

In both model, activation of LSTM is a tanh function, and recurrent activation is hard_sigmoid function. All of these parameters are updated during the training process on the data sets labeled via the back-propagation algorithm with an Adam optimizer with learning rate of 0.001. The batch size used was 64. The LSTM model has 38,115 parameters and the BiLSTM model have 89,315 parameters.

C. Experiments and Model Analyzing

Each model was trained for a maximum of 10 epochs. The recognition results of both proposed models are compared with the results of Douglas Coimbra de Andrade et al. [13] as shown in Table II and Fig. 7. That comparison proves that both proposed models have very good results.

TABLE II. ACCURACY RESULTS ON THE GOOGLE SPEECH COMMAND DATASET V1

Model	Accuracy (%)	Trainable Parameters	Epochs
Douglas Coimbra de Andrade	94.3	202K	40
Douglas Coimbra de Andrade(V2)	93.9	202K	40
Unidirectional LSTM (ours)	92.1	38k	10
Bidirectional LSTM (ours)	94.6	89k	10

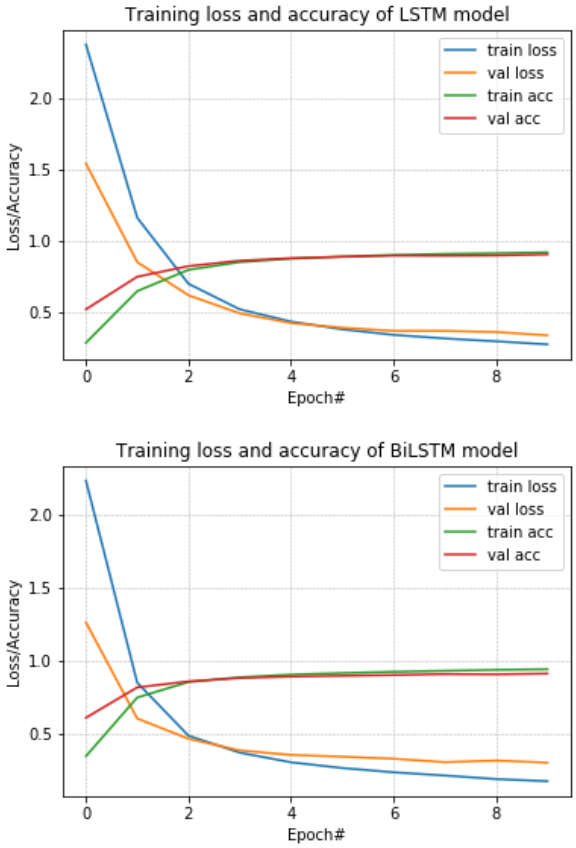


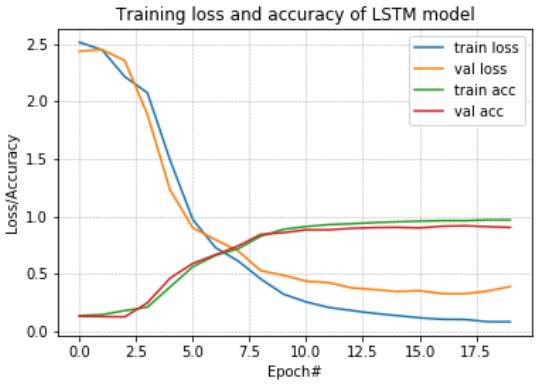
Fig. 7. Accuracy of LSTM (Above) and Accuracy of BiLSTM (Below).

IV. Apply to Recognition of Vietnamese Speech Commands

Using both of the above models for the collected Vietnamese command data set, the accuracy is shown in Fig. 8.

After 20 epochs, we can see that the BiLSTM model (98.19%) gives better results than the LSTM model (97.09%). However there is overfitting in both models. Next, dropout regularization is used for reducing overfitting and improving the generalization of deep neural networks technology. Dropout is a technique where randomly selected neurons are ignored during training, i.e. "dropped-out". This means that their contribution to the activation of downstream neurons is temporally removed on the forward pass and any weight updates are not applied to the neuron on the backward pass. Dropout in Keras is implemented by randomly selecting nodes with a given probability (e.g. 20%) after each update cycle. This creates a small random amount of noise during learning and makes the architecture more flexible when processing speech data. The results of both models with dropout are shown in Fig. 9 which have significantly reduced overfitting.

Classification report of BiLSTM and Confusion matrix for 15 speech commands with Background are also shown in Table III and Fig. 10. We see that the two most confused commands are Turn off the fan and turn on the fan (in Vietnamese).



(a) Training Loss and Accuracy of LSTM, 97.09%.

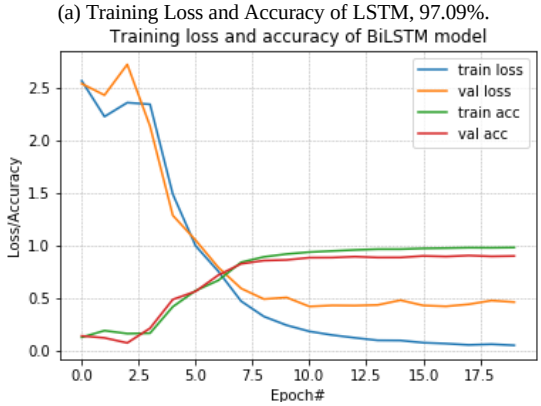
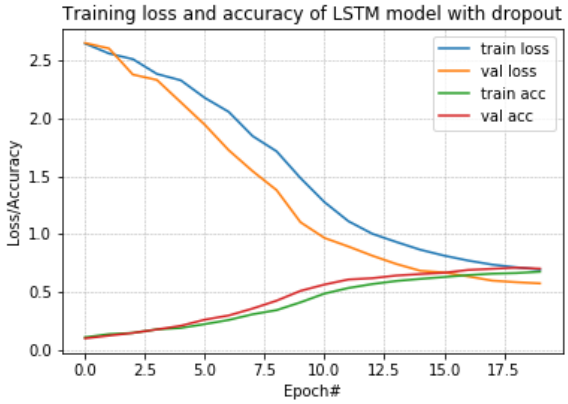


Fig. 8. (b) Training Loss and Accuracy of BiLSTM, 98.19%.



(a) Training Loss and Accuracy of LSTM with Dropout.

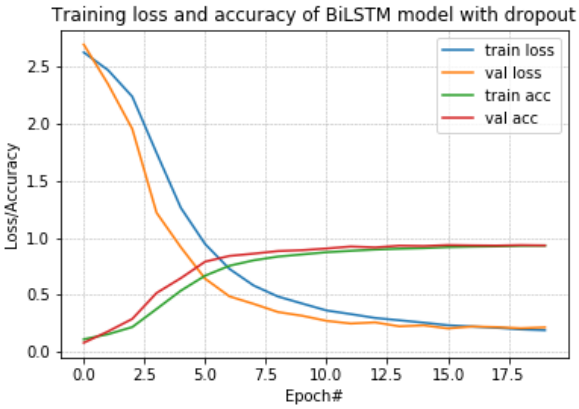


Fig. 9. (b) Training Loss and Accuracy of BiLSTM with Dropout.

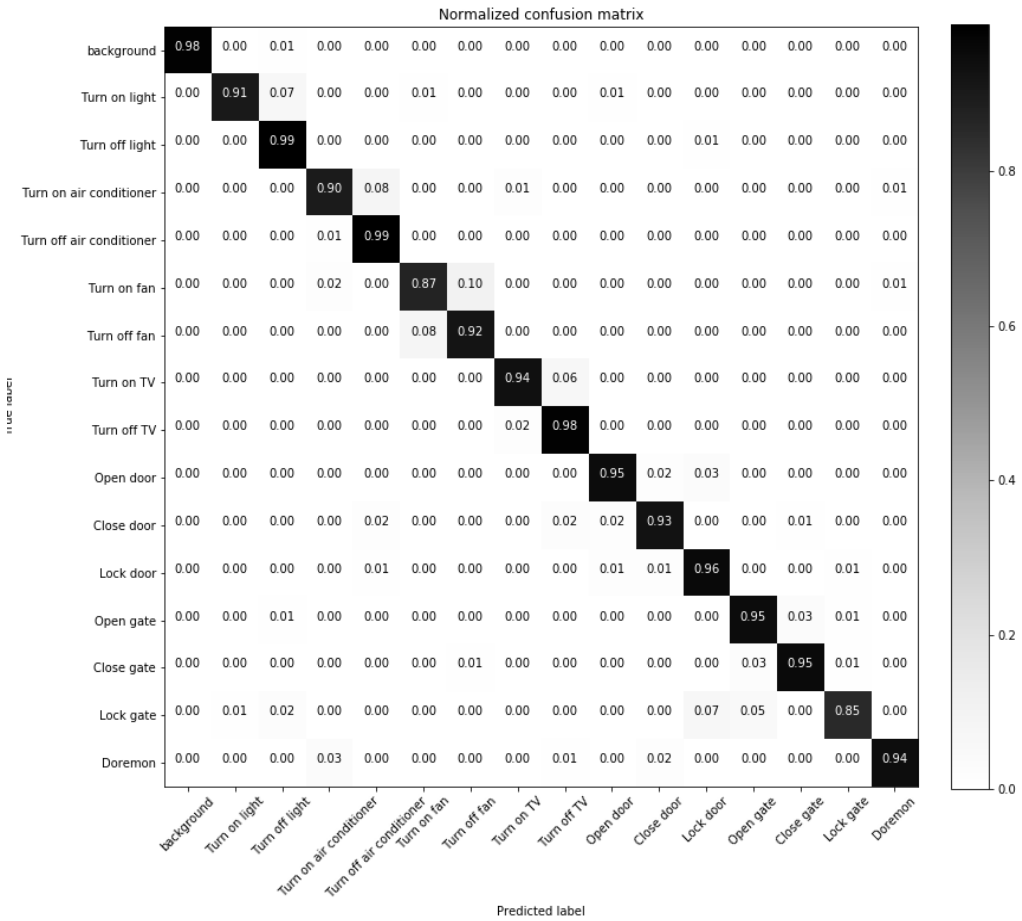


Fig. 10. Confusion Matrix of 15 Commands and Background.

TABLE III. CLASSIFICATION REPORT OF BILSTM

Command	precision	recall	f1-score	support
Turn on light	0.98	0.91	0.94	349
Turn off light	0.90	0.99	0.94	339
Turn on air conditioner	0.94	0.90	0.92	328
Turn off air conditioner	0.90	0.99	0.94	328
Turn on fan	0.90	0.87	0.88	328
Turn off fan	0.89	0.92	0.90	330
Turn on TV	0.97	0.94	0.95	330
Turn off TV	0.91	0.98	0.94	320
Open door	0.95	0.95	0.95	320
Close door	0.95	0.93	0.94	321
Lock door	0.89	0.96	0.92	321
Open gate	0.92	0.95	0.94	321
Close gate	0.96	0.95	0.96	318
Lock gate	0.98	0.85	0.91	320
Doraemon	0.98	0.94	0.96	329
Background	1.00	0.98	0.99	346

V. CONCLUSION AND PERSPECTIVES

This work contributes a Vietnamese command dataset including 15 commonly used commands for smart homes. After analysis and evaluation, we suggest using the BiLSTM model for recognizing Vietnamese speech commands. In addition, research also gives software for collecting data on Android and iOS. The identification result of the BiLSTM model on this dataset is very good, with accuracy averaging 98,19%.

The solution can be easily expanded on, for example adding commands, adding data. So, future results can be improved to better meet actual problems. The solution can also be transferred to other languages.

This work can serve as a good reference for many fields in Deep learning, for example, Pattern Recognition [14], CNN [15], Optimization Methods and Regularization in Deep learning [16], etc.

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Investigating Students' Acceptance of Online Courses at Al-Ahliyya Amman University

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***Abstract*—Online courses allow students to access the course materials anytime and anywhere. Those courses are meant to enhance and improve the learning processes. Unfortunately, by analyzing data of an online course in Al-Ahliyya Amman University, it was found that only 51% of enrolled students accessed the animated course material. This study proposed a model to understand the factors which affect students' intention to use an online course by extending the Unified Theory of Acceptance and Use of Technology (UTAUT) and Technology Acceptance Model (TAM). The proposed research model investigated the effects of experience, perceive usefulness, awareness, effort expectancy, cost, subjective (social) norms, and behavioral intentions to use online courses on students' adoption of online courses. Besides, the model investigated the effects of moderators, such as: college, college level, personal computer ownership, an internet access, and an online course enrollment on the relations. A questionnaire was distributed and then a structural equation modeling (SEM) approach was used to analyze the responses using SmartPLS.**

Keywords—TAM; UTAUT; online learning; e-learning

I. Introduction

To improve a process, including a learning process, using a computer-based solution such as online courses, the organization should encourage users to use the computer-based solution. Therefore, teaching institutions embedded many computerized solutions in the learning process, such as learning management system (LMS) [1, 2], assessment management system (AMS) [3], and online learning contents [4]. Those technologies can help in improving the learning process.

An online content is very important in order to encourage students to access it. The content provides an e-learning environment use, which is widely used to provide internet-based courses with different methods such as animation, graphic, text, and video streaming [5]. The better the content is, the higher the acceptance of the online courses is by the user [6]. Unfortunately, developing an interactive and animated content does not guarantee students' access to it. Al-Ahliyya Amman University offers some online courses. By analyzing the Remedial Computer Skills course, it was found that only 68% of the enrolled students accessed the LMS website of the course to view the syllabus, announcements, and blogs. Only 51% of the enrolled students viewed the course modules which are animated contents. Only 24% of the students attempted to practice the quizzes.

There are many studies that measured and analyzed the determinants that affect the efficient use of technologies, such as Technology Acceptance Model (TAM) [7] and Unified Theory of Acceptance and Use of Technology (UTAUT). Later, researches extended TAM and UTAUT to understand the acceptance of technology in education. [8-10]. However, those factors depend on the environment, culture, and other local criteria [8].

The primary objective of this study is to extend UTAUT to investigate students' intentions in adopting online courses. Section 2 presents the background and related work. Section 3 introduces the research model and the hypotheses. Section 4 shows the research methodology and the analysis. Finally, the paper is concluded by presenting the importance of the findings.

II. Background and Related Work

Davis, et al. [11] proposed the Technology Acceptance Model (TAM) to explain the factors that affect user's acceptance of an information system. The two primary factors of the model are: perceived usefulness (U) and perceived ease of use (EOU). These two factors determine the attitude toward using the system (A). Both (A) and (U) determine the behavior intention to use the system (BI). As a result, (BI) would affect and determine the actual use of the information system.

The Unified Theory of Acceptance and Use of Technology (UTAUT) was proposed by Venkatesh, et al. [12]. UTAUT was composed based on a review of eight models, which explained user's acceptance of technology. These eight models are: social cognitive theory (SCT) [13], TAM [7], theory of planned behavior (TPB) [14], innovation diffusion theory (IDT) [15], theory of reasoned action (TRA) [16], the model of PC utilization (MPCU) [17], the combined theory of planned behavior/ technology acceptance model (C–TPB–TAM) [18], and the motivational model (MM) [19]. UTAUT is based on four factors, which determine user's acceptance and behavior toward technology: performance expectancy (PE), effort expectancy (EE), social influence (SI), and facilitating conditions (FC). In addition, UTAUT is based on four moderators: gender, age, experience, and voluntariness of use.

Liu, et al. [5] integrated TAM and Flow Theory to predict student's acceptance of online-materials in MIS department in Christian University, Taiwan. The study found that text-audio-video materials in web-based proved more usefulness than other web-based materials. The study also showed that the easy

use of the web-based material affects directly on its usefulness and on learner's intentions. The intention to use the web-based learning is affected by three factors perceive of usefulness, perceive of easy use, and concentration.

Massive open online courses (MOOCs) are free-online courses. Gameel [6] studied learner's satisfaction of using MOOC. As a result of that, flexibility, content and perceived usefulness of MOOC had effects on learning acceptance of it, while learner's interaction with other learners or instructors had no effects on the acceptance of MOOC.

Many studies used UTAUT to understand students' acceptance of online courses. For instance, Liao, et al. [9] applied the UTAUT model, omitting the moderator effects, to understand the adoption of web-based learning. The study found that the effort expectancy was not significant on the use acceptance of web-learning, while performance expectancy, social influence, and facilitating conditions were significant.

General Extended Technology Acceptance Model for E-Learning (GETAMEL) [20] extended TAM. GETAMEL took into consideration five external variables: experience, subjective norms, enjoyment, computer anxiety, and self-efficacy. The study found that experience had significant effects on perceive ease of use, but no significant relation was found between experience and perceive usefulness.

III. The Research Model

The proposed research model extends UTAUT [12]. Like UTAUT, the proposed model adapts three of the four core determinants: perceive usefulness (PU), effort expectancy (EE), and social subjective norms (SN); but instead of the facilitating conditions determinant, perceive cost (COST) is adapted in the research model. Like GETAMEL [20, 21], experience (EXP) is used as a determinant; however, we distinguished between two kind of experience the computer literacy (EXP CL) and information technology experience (EXP2). The final determinant in the research model is awareness. Although awareness was considered in the acceptance of m-banking [22], we believe it would be significant in enrolling in online courses. The proposed model considers five moderators: college, college level, an internet connection, a personal computer ownership, and involvement in online courses. The factors considered in the research model are described as follows.

Experience with using information technology is how much time the user spends using the technology [12, 20, 22]. In this study, experience is divided into two sets: computer literacy (EXP CL) and Technical Knowledge (EXP2). EXP CL measures user's general knowledge of using computers for different purposes, while EXP2 measures user's capabilities in managing files skillfully. Awareness (AW) means that a learner has the knowledge of online courses, the availability and the use of technology in learning [23]. In respect of the awareness factor, the study offered that some courses should be compulsory, while other ones should be elective, which may not be taken. Awareness measures students' knowledge of the availability of online courses and their environment. Perceive Usefulness (PU) was introduced by Davis [24]. PU means the degree to which a student believes that online courses would enhance his\her learning process. Effort Expectancy (EE) means that learning based on using online courses are free of effort [11, 20]. Perceive Cost of Use means the direct and indirect cost of using the technology [22] such as fees, hardware costs, software costs and operation costs. Subjective Norm (SN) means the influence of people on students to use the online courses [20]. The final factor is Behavioral Intention to Use (BI). BI is the decision to adopt the online learning.

A. The Research Hypotheses

Ten hypotheses illustrated in Fig. 1 were developed in this study to analyze the factors that affect student's adoption of online courses.

- H1: EXP CL influences PU
- H2: EXP2 influences EE
- H3: SN influences BI
- H4: COST influences BI
- H5: The influence of PU on BI is moderated by COLLEGE
- H6: The influence of PU on BI is moderated by Enrolled Online
- H7: The influence of EE on BI is moderated by Enrolled Online
- H8: The influence of EE on BI is moderated by PC
- H9: The influence of EE on BI is moderated by INTERNET_CONNECTION
- H10: The influence of AW on BI is moderated by STUDENT_LEVEL

B. Methodology

Quantitative method was utilized, in the form of a non-structured survey questionnaire with closed questions, using a 5-point Likert-type scale. Prior to the survey, a pilot study was conducted to assure the reliability and validity of the questionnaire. The entire instrument demonstrated acceptable reliability; Cronbach's alpha was 0.979. The questionnaire was randomly distributed to Al-Ahliyya Amman University students. The final accepted questionnaire for analysis was 385 out of 395 from the response rate. The data were analyzed using SPSS version 25 and SmartPLS3.

C. Data Analysis

The colleges were classified into three groups: Faculty of Engineering and Faculty of Information Technology (Eng&IT); Faculty of Pharmacy, Faculty of Medical Sciences and Faculty of Nursing (Med); and Business School, Faculty of Law, Faculty of Arts & Sciences and Faculty of Architecture & Design (Humanities). The responses according to the college were as following: Med (34%), Eng. & IT (41%) and Humanities (25%) (see Table I).

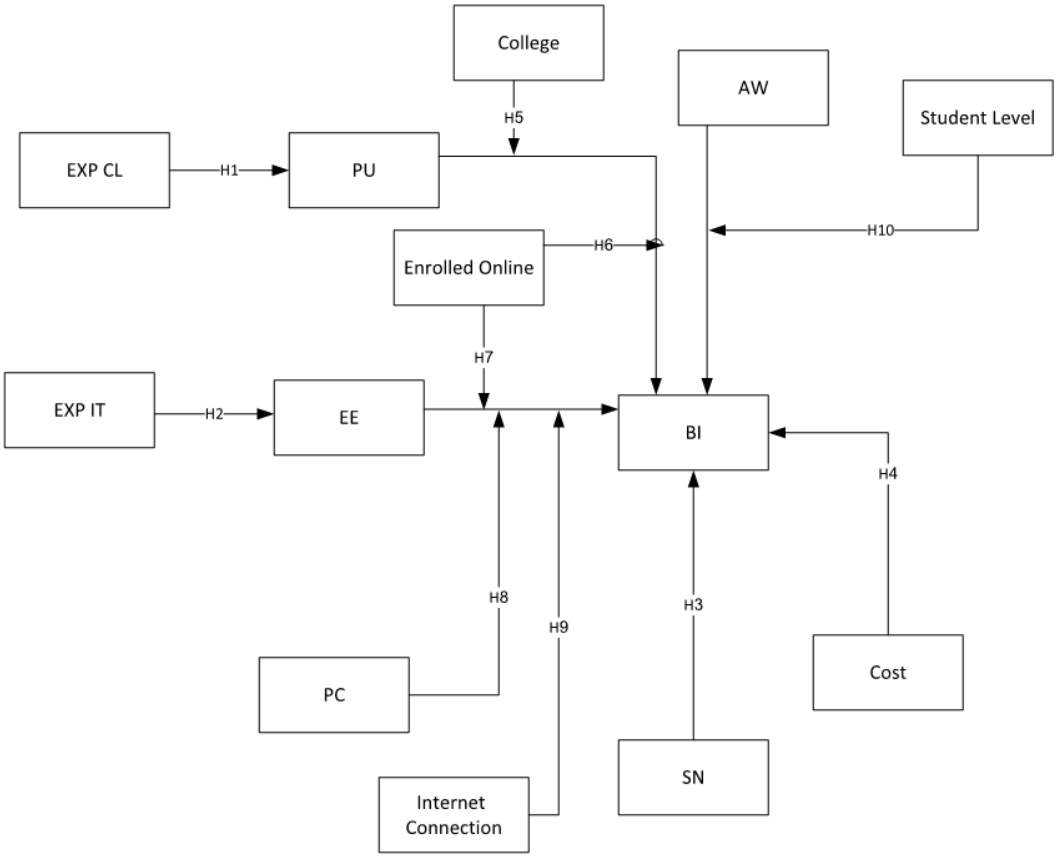

Fig. 1. The Research Model.

TABLE I. STUDENT DISTRIBUTION OVER COLLEGES

College	Frequency	Percent
Med	131	34
Eng. & IT	158	41
Humanities	96	25
Total	385	100

College levels are categorized into a 4 year-program for humanities, nursing, Information Technology, and medical sciences, while engineering and pharmaceutical sciences programs are a 5-year program. The responses according to college levels were as following: first year student (23.1%), second year student (26.0%), third year student (24.4%), fourth year student (23.4%), fifth year student (3.1%) (see Table II).

338 students (87.7% of the sample) own personal computers while 48 students (12.2% of the sample) did not. Most of the students had fast internet connection (90.4%) while only 37 students (9.6% of the sample) did not have. Only 64 students (16.6%) have never enrolled in online courses while the others have, as shown in Table III.

From Fig. 2 and Table V, all item factor loadings are (> 0.50) which are acceptable [25, 26]. All the results are shown in details in Table V.

D. Hypotheses Testing

The direct effects were analyzed using SmartPLS3, and the results are shown in Fig. 2.

TABLE II. STUDENT DISTRIBUTION OVER COLLEGE LEVELS

Level	Frequency	Percent	Valid Percent	Cumulative Percent
1	89	23.1	23.1	23.1
2	100	26	26	49.1
3	94	24.4	24.4	73.5
4	90	23.4	23.4	96.9
5	12	3.1	3.1	100
Total	385	100	100	

TABLE III. STUDENT ENROLMENT IN ONLINE COURSES

Number of Online Courses	Frequency	Percent	Valid Percent	Cumulative Percent
0	64	16.6	16.6	16.6
1	90	23.4	23.4	40
2	97	25.2	25.2	65.2
3	56	14.5	14.5	79.7
4	28	7.3	7.3	87
5	21	5.5	5.5	92.5
6	9	2.3	2.3	94.8
7	5	1.3	1.3	96.1
9	15	3.9	3.9	100
Total	385	100	100	

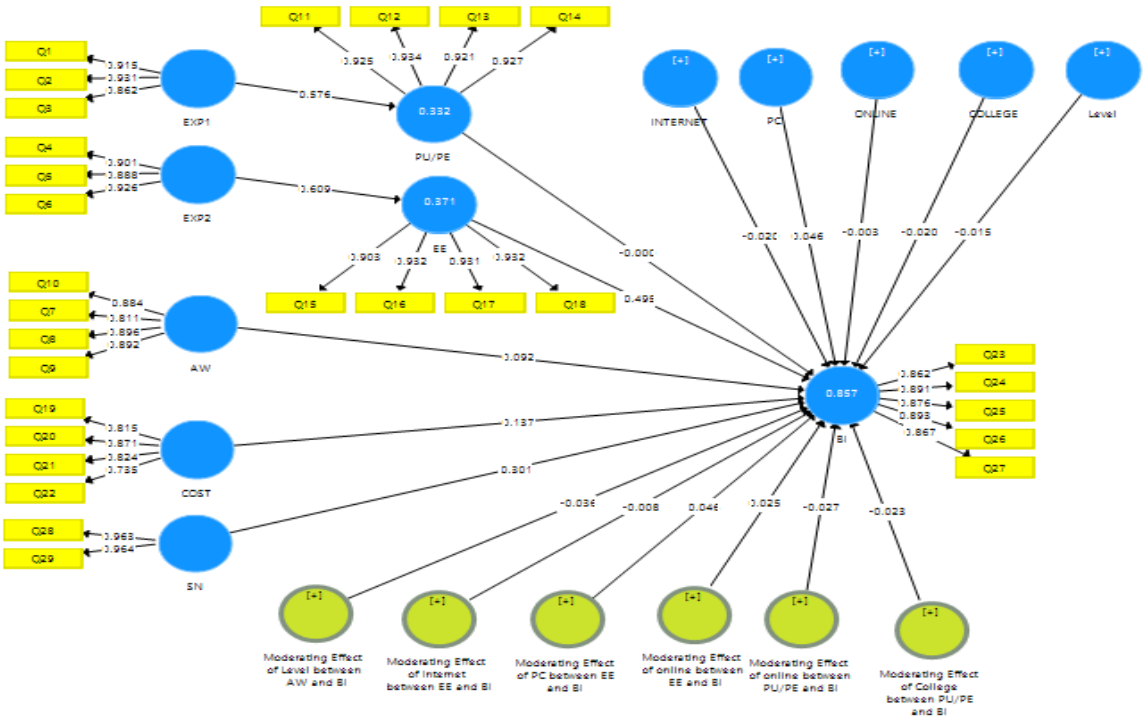

Fig. 2. Measurement Model.

The reliability was analyzed, and the results are shown in Table VI. Cronbach's Alpha values for all variables were acceptable since the values were (> 0.70) and ranged from 0.832 to 0.945. Composite Reliability (CR) was acceptable since the values were (>0.70) and ranged from 0.886 to 0.963). Average Variance Extracted (AVE) was acceptable since the values were (>0.50) and ranged from 0.661 to 0.928). The results of SmartPLS are shown in Fig. 3 and Table VII.

The descriptive statistics are shown in Table IV. The mean values range from 3.56 to 4.00, and the standard deviations range from 0.91 to 1.14. Thus, students generally are aware of online courses, their benefits, and of online learning environment. The internal reliability of the factors is acceptable, since Cronbach's alpha values range from 0.83 to 0.95.

TABLE IV. FACTOR DESCRIPTIVE STATISTICS

Factor	N	Mean	Std. Deviation	Cronbach's Alpha
EXP CL	385	3.8043	0.96365	0.887
EXP2	385	3.9957	0.90889	0.89
PU	385	3.7273	1.06753	0.945
EE	385	3.8896	0.98102	0.943
AW	385	3.7552	0.94182	0.894
COST	385	3.5623	0.96404	0.832
SN	385	3.6584	1.14204	0.922
BI	385	3.8618	0.95907	0.926
Valid N (listwise)	385			

H1: EXP CL influences PU: The results show that EXP CL influences PU with T-Statistics were 13.414 and p = 0.001. Hence, the computer literacy affects the decision of perceive usefulness of online courses. If students have general knowledge of using computers, they will understand the benefits of using online courses.

H2: EXP2 influences EE: The results show that EXP2 influences EE with T-Statistics were 13.112 and p = 0.001. Therefore, having knowledge of managing files on computers and solving some technical problems will affect the reduction of effort needed to use online courses.

H3: SN influences BI: The results show that SN influences BI with T-Statistics were 5.918 and p = 0.001. In other words, a social advice from a friend or an advisor will encourage students to use online courses.

H4: COST influences BI: The results show that COST influences BI with T-Statistics were 3.871 and p = 0.001. The students are aware of the direct and indirect cost of online courses.

H5: The influence of PU on BI is moderated by COLLEGE: This hypothesis was not supported since the reported values of T-Statistics were 0.822 and p = 0.411. Therefore, student's major does not affect his\her behavioral intention to use the online courses. Neither the direct relation between PU and BI nor the moderated relations were supported.

H6: The influence of PU on BI is moderated by Enrolled Online: This hypothesis was not supported since the reported values of T-Statistics were 0. 468 and p = 0.64. Neither the moderated relation nor the direct relation between PU and BI were supported.

H7: The influence of EE on BI is moderated by Enrolled Online: This hypothesis was not supported since the reported values of T-Statistics were 0. 465 and p = 0.642. Although the moderated relation was not supported, the direct relation between effort expectancy and behavioral intention to use online courses was supported. The reported values of T-Statistics were 8.164 and p = 0.001. The friendlier the online course is, the higher the behavioral intention to use it is.

H8: The influence of EE on BI is moderated by PC: This hypothesis was not supported since the reported values of T-Statistics were 1.646 and p = 0.1. However, the direct relation was supported. Owning a personal computer did not affect student's decision to use an online course.

H9: The influence of EE on BI is moderated by INTERNET_CONNECTION: This hypothesis was not supported since the reported values of T-Statistics were 0.294 and p=0.769. However, the direct relation was supported. Having an internet access did not affect student's decision to use an online course.

H10: The influence of AW on BI is moderated by STUDENT_LEVEL: This hypothesis was not supported since the reported values of T-Statistics were 1.557 and p = 0.12. However, the direct relation was supported since the reported values of T-Statistics were 2.432 and p = 0.015. Student's awareness of online courses affects the behavioral intention to use it.

TABLE V. ITEM FACTOR LOADINGS

Item	*AW*	*BI*	*COST*	*EE*	*EXP CL*	*EXP2*	*PU/PE*	*SN*
Q1					0.915			
Q2					0.931			
Q3					0.862			
Q4						0.901		
Q5						0.888		
Q6						0.926		
Q7	0.811							
Q8	0.896							
Q9	0.892							
Q10	0.884							
Q11							0.925	
Q12							0.934	
Q13							0.921	
Q14							0.927	
Q15				0.903				
Q16				0.932				
Q17				0.931				
Q18				0.932				
Q19			0.815					
Q20			0.871					
Q21			0.824					
Q22			0.735					
Q23		0.863						
Q24		0.89						
Q25		0.875						
Q26		0.893						
Q27		0.868						
Q28								0.963
Q29								0.964

TABLE VI. CONSTRUCT RELIABILITY AND VALIDITY

	Cronbach's Alpha	*rho_A*	*Composite Reliability (CR)*	*Average Variance Extracted (AVE)*
AW	0.894	0.904	0.926	0.759
BI	0.926	0.926	0.944	0.771
COST	0.832	0.842	0.886	0.661
EE	0.943	0.945	0.959	0.855
EXP CL	0.887	0.894	0.93	0.816
EXP2	0.89	0.893	0.932	0.819
PU/PE	0.945	0.946	0.961	0.859
SN	0.922	0.923	0.963	0.928

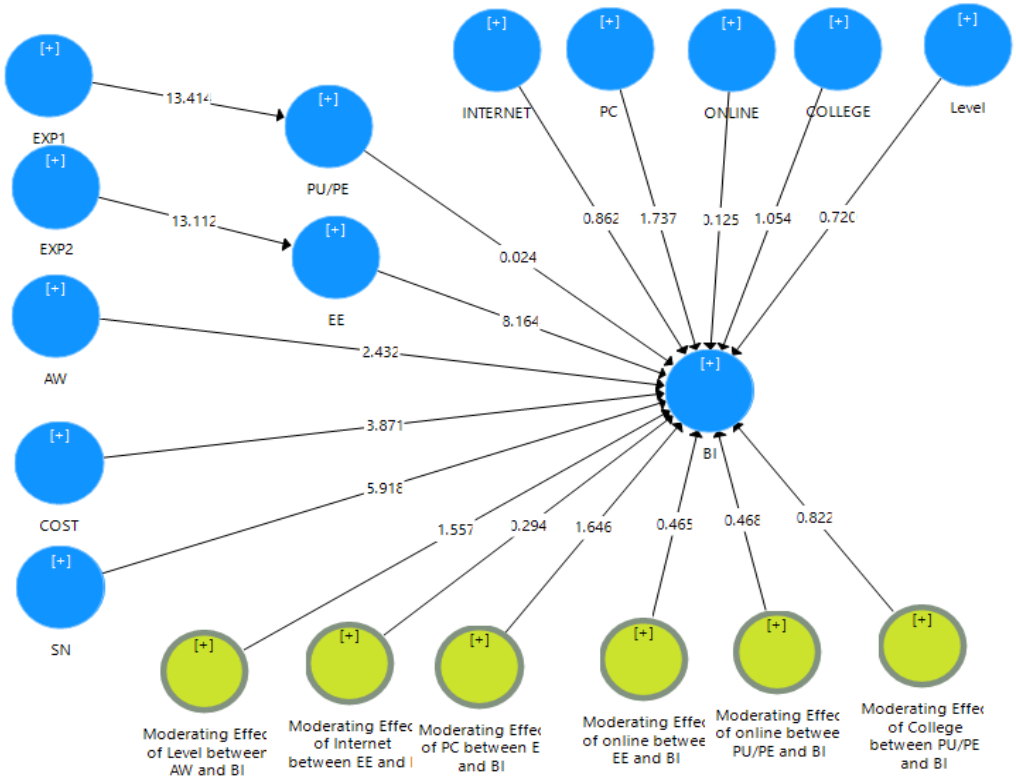

Fig. 3. Hypotheses Structural Model.

TABLE VII. BOOTSTRAPPING

	Original Sample (O)	*Sample Mean (M)*	*Standard Deviation (STDEV)*	*T Statistics (|O/STDEV|) ***	*P Values **	*Decision*
AW -> BI	0.091	0.094	0.037	2.432	0.015	Supported
COST -> BI	0.137	0.139	0.035	3.871	0	Supported
EE -> BI	0.494	0.491	0.061	8.164	0	Supported
EXP CL -> PU	0.576	0.576	0.043	13.414	0	Supported
EXP2 -> EE	0.609	0.609	0.046	13.112	0	Supported
Moderating Effect of College between PU and BI -> BI	-0.023	-0.022	0.028	0.822	0.411	Not Supported
Moderating Effect of Internet-connection between EE and BI -> BI	-0.008	-0.001	0.028	0.294	0.769	Not Supported
Moderating Effect of Level between AW and BI -> BI	-0.036	-0.033	0.023	1.557	0.12	Not Supported
Moderating Effect of PC between EE and BI -> BI	0.046	0.043	0.028	1.646	0.1	Not Supported
Moderating Effect of online between EE and BI -> BI	0.024	0.012	0.051	0.465	0.642	Not Supported
Moderating Effect of online between PU and BI -> BI	-0.026	-0.014	0.055	0.468	0.64	Not Supported
PU -> BI	0.001	0.005	0.056	0.024	0.981	Not Supported
SN -> BI	0.302	0.295	0.051	5.918	0	Supported

*Significant p <= 0.05

** Significant T Statistics >= 1.96

IV. CONCLUSIONS

This study proposed a model extending Unified Theory of Acceptance and Use of Technology (UTAUT) to investigate the factors that influence students to use online courses. The factors which were included in the models were: experience, perceive usefulness, awareness, effort expectancy, cost, subjective (social) norms and behavioral intention to use online courses. In addition to the effects of these moderators: college, college level, personal computer ownership, internet access, and online course enrolment were investigated. The study was conduct at Al-Ahliyya Amman University to investigate the factors which affect students' adoption of online courses.

By testing the hypotheses using the structural equation modeling (SEM) approach and SmartPLS, it was found that effort expectancy, subjective (social) norms, cost, and awareness of online course availability affect the behavioral intention to use online courses. Unlike the findings of effect, which were not significant in the social norms on behavioral intention to use in South Eastern University of Sri Lanka (SEUSL) [10], it was found that the subjective (social) norms were significant in Al-Ahliyya Amman University. In a similar study of [10] [8], effort expectancy was significant on behavioral intention to use online courses. Whereas in Vululleh [8] study, the relation between perceive usefulness and behavioral intention to use online courses could not be approved. The effects of awareness of the online courses and their costs were significant on the behavioral intention to use the online courses.

By testing the effects of the moderators, none of them was significant. In other words, student's major, college level, owing a personal computer or having an internet access would affect student's decision to enroll in an online course. Al-Ahliyya Amman University provides a free wireless Internet access in campus; as well, the computer labs are free to be used by students after 2 PM. As result, having a personal computer or an internet access do not affect the adoption of online courses.

In conclusion, the technical knowledge (EXP2) of using the computer for online access, awareness of online courses availability, subjective (social) norms, cost, and effort expectancy were found significant on behavioral intention to use online courses; therefore, the university should adopt a strategy to focus on those factors. An academic advice should inform the students about the availability and advantages of online courses. This would increase student's awareness and subjective norms. New student orientation should include some workshops about online courses to increase their technical experience and effort expectancy. Finally, the elective courses that are online should have reduced fees to encourage students to enroll in online courses.

There are some limitations in this study. The questionnaire was distributed in an electronic format using the Learning Management System (LMS). Another limitation is that the sample was randomly selected from only one private university. Also, the study did not distinguish between compulsory and optional online courses. Therefore, those issues should be taken in consideration in future work. The study should be extended to include sample from more than one university. Also, Subjective norms and social factors should include more elements to study the effects of the social and environment on the behavioral intention.

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A Comprehensive Evaluation of Cue-Words based Features and In-text Citations based Features for Citation Classification

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***Abstract*—Citation plays a vital role in the scientific community of evaluating the contributions of scientific authors. Citing sources delivers a measurable way of evaluating the impact factor of journals and authors and allows for the recognition of new research issues. Different techniques for classifying citations have been proposed. Citations that provide background knowledge in the citing document have been classified as non-important or incidental by previous researchers. Citations that extend previous work in the citing document are classified as important. The accuracy achieved by existing citation models is not much higher. Better features need to be included for accurate predictions. A hybrid approach would present all possible combinations of cue-words and in-text citation-based features for citation classifications.**

***Keywords*—Cue-words; in-text citation; hybrid**

I. Introduction

Why are citations important? This question has grabbed many authors' attention in recent decades, and a variety of different answers were found in the existing literature. Citations are important because journals base their impact factor on them. Author rankings and awards also rely on citation-based measurements. The quality of work is measured by how often it is cited by others and whether it extends the work of others. Highly cited works in the research community mean recognition and a greater impact on scholarly research. Researchers recognize diverse causes of citations; however, past analysis shows that not all citations are equal. Some citations extend current works using the same algorithms and comparing results, whereas others are used as background knowledge that are from the same domain but do not directly influence the new work. Different techniques have been proposed to classify citations; these are identified as important and non-important. Citations that provide background knowledge for the citing document have been classified as incidental by previous researchers. In the scholarly community, different researchers have claimed that some authors unintentionally read cited papers incorrectly [1], [2] merely to fill up the citations section. Other errors that occur include page and volume number not being the same in the cited section. Some authors claim that 40% of citations are copied to fill in the reference section without being cited in the paper [3], [4], [5]. This work describes references using multiple feature types that influence the research community on citing research articles. These are influential references which contribute to citing papers such as new ideas, research problems, methodologies, and experiments. An automated system was proposed by [6] to classify citations into two classes: negative and positive. Past analysis shows that not all citations are treated equally, such as those deemed essential vs. non-essential or non-important. Recently [7], [8] contributed to the research community by being the first to tackle the problem of identifying important citations. Citations that provide background knowledge in the citing document are classified as incidental by previous researchers. Citations that extend previous work in the citing document are classified as important. Their approach is to use different features to identify important and incidental citations. These include total number of direct citations, number of direct citations per section, total number of indirect citations, and number of indirect citations per section. Author overlap is also considered helpful, where citations appear in tables or captions. Features also include number of reference, number of paper citations or all citations, similarity between abstracts, page rank, number of total citing papers after transitive closure, and the field of cited paper. Based on these features, they identify important and incidental citations. Our work is similar to Valenzuela et al; we make a detailed comprehensive evaluation of all possible combinations of cue-words based features and in-text based features and create a hybrid approach to classifying citations. In the literature review, we identified a research gap in that no one has detailed all possible combinations of cue-words based, in-text based, and hybrid features to evaluate the best feature among them.

1) Cue-words: In this feature, we use cue-words from the sentence in which the citations occur. We selected the sentence where citations appear and one sentence before the citations and one sentence after the citations appear. We collected all citations in the respective paper and counted the words.

2) Cue-words count: In this feature, we counted cue-words and checked the occurrence of each cue-word in the whole paper.

Section cue-word count: In this feature, we counted cue-words and checked the occurrence of single cue-words in each section to identify the word's importance.

3) In-text count: In-text citations which the author uses to support background knowledge or to extend previous work within the whole paper.

Section in-text count: In this feature, we use an in-text count and check the occurrence of single in-text within each section to identify importance of each citation.

4) Hybrid: all possible combination of cue-words bansed features and in-text citations based features.

The rest of the paper is divided in five sections, including related work, methodology, experimental results and discussion, conclusion, and future work.

II. Related Works

Considerable effort has been made to improve the citation classification system in the past decades. Many authors contribute different approaches to examine citation classification. Some reasons why authors cite a work include [9]:

- Criticized for weak work by the community.
- Appreciation for great effort by the research community.
- To provide background knowledge.
- To reference tools and techniques.
- To strongly disagree with those who claim others' work.

Garzone [10] introduced 35 different categories of classifying citation functions based on cue phrases. This work is based on different combinations of schemes, but the focus is on [11] the scheme with limitations applied. We further subdivided the information into 10 top level categories after all processing was complete. They were the first to claim a new fully automated classification scheme [12], [13]. The automatic scheme inputs entire articles. The results return different citations along with different sets of functions. The literature dealing with the important function of cue phrases in citation classification was given unique consideration. The study relies exclusively on cue-phrase features and content citation-based features for classifying as important and identical. According to CiTO citation typing ontology [14] [15], they identified 90 semantic relationships between papers and citations. In [5] author describes references using multiple types of features; they had a strong influence on the research community in the citing research article. These are some influential references which contribute in citing papers: new ideas, research problems, methodologies, and experiments. According to [5], the classification of these citations would be two broad categories: 1 important and 2 non-important.

Author in [16] presents a technique called a novel automated technique, which classified as sentiment positive or sentiment negative. In this technique, the citations appearing in citing papers are extracted using the sentiment lexicon then classified into positive and negative. The data set was 150 research papers and they used classifier Naive Bayes for sentiment analysis. The approach used in this research work for classifying citations is as follows:

- TYPE I: Positive
- TYPE II: Negative
- TYPE III: Neutral

In TYPE I: Accuracy achieved in precision 0.84, recall 0.94 and f-measure 0.89: Positive results against support of 109 research papers. In TYPE II: Negative precision 0.25, recall 0.10 and f-measure 0.14 results against support of 21 papers.

They used a dataset to classify citations for this research work consisting of 2829 citations against 116 research papers. Every citation in the above-mentioned categories was tagged manually for citation classification and used 10-fold cross validation. [17] proposed a technique that supervised the citation classification function. The system is categorized into four levels:

- Neutral category: didn't appreciate or criticize any approach in this category.
- Contrast Category: compared different approaches.
- Positive Category: made agreement or compatibility with existing techniques.
- Weak Category: criticized the cited weak work.

They used 548 citations of adopted supervised learning in these categories:

- CoCoGM: compared the methodology and goal of the research article.
- PMot: motivation for the work.
- PSim: similarity between both works citing and cited paper.
- PSup: current work is based on previous work.
- Coco: cite the superior state of author's work.

This experiment was applied on datasets of 116 research articles; precision 0.75, Kappa 0.59 and Micro f 0.68 were calculated.

Cue phrases were used to classify citation system in KAFTAN, presented by [18]. The four categories to classify citations are as follows:

- Basis: In this Category based on another work.
- Support: In this Category supported by other work.
- Limitation: In this Category criticizing the cited work on its weaknesses.
- Comparison: In this Category comparing different approaches.

The technique is to describe several features based on different types of polarity and context-level features such as 1) grouping referencing; 2) tagging referencing; and 3) polity and non-syntactic referencing removal [17][19]. Support vector machine (SVM) and Random forest (RF) classifier used for citation classification. Accuracy achieved precision 92%, recall 76.4% and f-measure 70.5% used 10-fold cross validation. [20] Hassan technique expanded [7] work and proposed 14 different features to classify citations. Grouped into three main categories such as context-based features, cue-words based features and textual features. These features are evaluated according to five different classifiers: K Nearest Neighbor (KNN), SVM, RF, Naive Bayes, and Decision Tree. The best classifier identified with the highest accuracy is RF with 91%.

Author in [21] compared and built a technique that classifies citations into important vs. non-important. They used four different state-of-the-art datasets of their work with 64 different features, 29 of which are for Extra Tree Classifier. They manually selected 450 annotated citations and classified the citations using RF and SVM classifiers. They used 20,527 research articles from a well-known dataset, with 106,509 citations chosen against the dataset. In [22][23], the author describes citation function and polarity to classify them using a scheme of eight categories, which helps show the importance of citations in the community. This paper is in the biomedical domain. The dataset used 640 biomedical research articles and collected 1,823 meaningful citations for polarity and experiments. Set of two main features used to automatic citation classification, such as Part-of-speech tags (POS) and word n-gram using a machine learning algorithm to classify citations into eight categories using Maximum Entropy and SVM classifiers against meaningful citations to generate results.

Positive: in this class, the author agrees with previous work or extends it; two categories belong to this class: Confirmation precision 0.822, recall 0.638 and f1-score 0.719. and Being-confirmed. precision 0.77, recall 0.42 and f1-score 0.54.

Negative: in this class, the author disagrees with previous work for these reasons: weakness of the previous work, data not satisfying. Two Categories belong to this class: Contrast/Conflict precision 0.77, recall 0.52 and f1-score 0.62. Unsolved precision 0.554, recall 0.463 and f1-score 0.504.

Neutral: in this category, the author was not criticized and previous work was not appreciated. Four categories belong to this class: Perfunctory/Background, precision 0.67, recall 0.792 and f1-score 0.736. Statement precision 0.802, recall 0.582 and f1-score 0.674. Comparison precision 0.557, recall 0.788 and f1-score 0.653. and Multi-comparison precision 0.552, recall 0.431 and f1-score 0.484.

Here are the results for detailed feature combinations on citation function classification: The SVM classifier with POS tags + 1-3 grams + dependencies features achieved the best result. An automated system was proposed by [6] to classify citations into two classes: negative and positive. Past analysis shows that all citations are not treated equally, such as essential or non-essential/non-important. Recently in the research community [7]. They became the first to tackle this problem by identifying important citations that are referred to for providing background knowledge in the citing document. These citations are categorized in the class of incidental by previous researchers. Citations which referred to previous work in the citing document were categorized in the class of Important. Their approach is to use different features to identify important and incidental citations. These features are: Total number of direct citations, Number of direct citations per section, Total number of indirect citations and number of indirect citations per section, Author overlap, is considered helpful, citations appear in the table/caption, 1/number of reference, number of paper citations/all citations, Similarity between abstract, PageRank, Number of total citing paper after transitive closure, field of cited paper. On the bases of these features they identify important citations. A new term is used in the research community by Valenzuela, who categorized citation into important vs. incidental. These categories were sub-divided into two further categories: Important, Using others' work, and expanding on others' work. Incidental: Related work and Comparison. These categories were evaluated using 12 different features to classify citation:

- (F1) Total number of direct citations:
- (F2) Total number of direct citations per section:
- (F3) Total number of indirect citations and number of indirect citations per
- section:
- (F4) Author overlap:
- (F5) Is considered helpful:
- (F6) Citation appears in table or caption:
- (F7) 1/number of references:
- (F8) Number of paper citation / all citations:
- (F9) Similarity between abstracts:
- (F10) PageRank:
- (F11) Number of total citing papers after transitive closure:
- (F12) Field of the cited paper:

Author in [24] proposed a technique that classifies binary citation. This scheme is based on metadata and content-based parameters to classify citations. Faiza is the first to classify

citation as important vs. non-important using metadata-based hybrid parameters. Two types of datasets were used in this work: D1 and D2. Dataset D1 consists of a standard dataset which means it is authentic, published in top of the conference and even latest in the current domain. The dataset used 20,575 research articles which have 106,509 citations; among those, 465 annotated pairs of paper datasets are used in D1. D2 consists of pairs of 488 papers with best source and annotated (citing papers) citations. Features were used to classify important vs. non-important citations. There are two different types of parameters: metadata based and content based.

- Metadata

Title, Author name, key-word, Category, Reference.

- Content-based Abstract,

Cue-phrase set of static cue-phases used in this work.

WEKA Machine learning tool is used for classifications with the help of these classifier to generate results against dataset.

- SVM
- KLR
- RF

The generated results are better than the benchmark precision achieved on SVM 0.68, KLR 0.62 and RF 0.72. The similarity of our work is based on identifying important citations by [7], [21] and [24]. Authors describe how not all citations are treated equally. They categorized citation into important and non-important classes. Citations were classified into important and incidental using different features. The classifiers used to evaluate citations were SVM, KNN, Naive Bayes and RF. The dataset used for this thesis contained 465 research articles from the computing domain form ACL anthology. Only 14% of the citations calculated as important and the rest were incidental citations. The evaluation criteria were Precision, Recall, and f-measure. After a comprehensive study of the literature, the state-of-the-art approaches were found in the same domain. We found that methods for citation classification are based on linguistic cue phrases and In-text citations. The concise sign of these approaches is described in Table 2.1 with references, methodologies, strengths and weaknesses. In this thesis, we begin with a literature review of the citation classification. The varieties of classification techniques and their automatic classification schemes with machine learning algorithms were closely observed. In [16] present a technique called a novel automated technique that classified sentiment positive or sentiment negative. In this technique, the citations appearing in citing papers are extracted using the sentiment lexicon; then they are classified into positive and negative. Author in [9] introduced 35 different categories of classifying citation functions based on cue phrases. This work is based on a different combination of schemes, where the focus is on [11] and the scheme applies limitations to it. Author in [17] proposed a technique that supervised for citation classification function; this system is categorized into four different levels: Neutral, Contrast, Positive, and Weak. The average SVM accuracy achieves precision 0.83, Kappa 0.84, and Micro f 0.83 and RF accuracy has Precision 0.83, Kappa 0.84, and Micro f 0.83. The literature reviews that deal with the important function of cue phrases in citation classification were given unique consideration. CiTO citation typing ontology [14]; according to [15], they identified 90 semantic relations between papers and citations. [16] presents a technique called a novel automated technique, which classifies sentiment positive or sentiment negative. Author in [5] describes references using multiple feature types; they had a strong influence on the research community in the citing research article. These are some influential references which contribute to citing papers, such as new idea, research problems, methodologies, and experiments. According to [5], the classification of these citations would be two broad categories: one important and two non-important. In [24] proposed a technique that classifies binary citation; this scheme is based on metadata and content-based parameters to classify citation. Faiza was first to classify citations as important and non-important using metadata-based hybrid parameters. Two types of dataset set were used in this work: D1 and D2. Dataset D1 consists of a standard dataset which means authentic, published in top of the conference, and even latest in the current domain. The generated results are better than the benchmark precision achieved on SVM 0.68, KLR 0.62 and RF 0.72. Authors [22] and [23] describe citation functions and polarity for classification. This helps us understand the importance of citations in the research community. To classify, eight categories are merged in three main categories. Maximum Entropy and SVM classifiers against meaningful citations generated the following results: Neutral precision - 0.806, recall 0.931, and F1 0.838. Positive precision - 0.806, recall 0.931, and F1 0.838; and negative precision 0.806, recall 0.931, and F1 0.838. Author in [21] compared and built a technique that classified citations into important and non-important. They used four different state-of-the-art datasets for their work. They used 64 different features, 29 of which are for Extra Tree Classifier. RF and SVM are the classifiers used for classification. The average SVM results were: precision 0.87, recall 0.89, and f-measure 0.84, and RF accuracy was precision 0.9, recall 0.91. and f-measure 0.91.

III. METHODOLOGY

The literature review was critically examined to explore the different techniques proposed by different authors to classify citations. In citation related studies, the main purpose is identifying and classifying citations. Recently [7] published an article at the AAAI conference on the A1 category. Valenzuela classifies citations into two broad categories: important and non-important. In this thesis, to classify citations using the above-mentioned broad categories, we proposed a new technique using a different combination of cue-words based and in-text-based features to classify the citations that are evaluated in the proposed methodology in Fig. 1. An architecture diagram explains our proposed methodology. In this thesis we use Valenzuela et al.'s 2015 publicly available dataset as a benchmark and Scholarly Big data for experiments published in the AAAI workshop. To evaluate our features, we performed some experiments on the collected dataset to show which features perform better on which classifiers. Author in [25] used four standard label mapped sections: Introduction,

Related work, Methodology and Results. We performed preprocessing on the collected dataset applying the stemming and stop words removal algorithm. After preprocessing, we removed duplicate words and the remaining list is a list of unique words that allow us to evaluate all possible combinations of features. We used four different classifiers: Random Forest RF, Support Vector Machine SVM, Naive Bayes, and KNN. We computed each model on the same dataset and calculated precision, recall and f-measure. For the training and testing of data, samples were studied using the 10 cross fold validation method, and SMOTE was applied to balance the dataset with synthetic value and minority class on the collected dataset for the experiment performed. Python was used for evaluation and generated results and compared with benchmark.

A. Experimental Dataset

We collected a data set of 416 papers downloaded from the ACL anthology. Approximately 21,500 words were extracted from the dataset to classify citations. 14,000 words were marked as incidental and 7500 words were marked as important. Next preprocessing was applied on the collected words. Onix Text Retrieval Toolkit stop word List was applied for stop word removal from the collected dataset, and a suffix-stripping algorithm was used for stem words in their root form. We removed duplicate words from data which was generated after stop word and stemming was applied. A total of 858 unique words were found and two different files were created. One file contains 631 unique words marked as incidental class and another file contains 227 unique words marked as important class. We used [7] dataset as benchmark which is publicly available for experiments. There are four fields in the dataset. Annotator [25] is used in first field; the Paper field contains the ID of the root paper; the second field contains the Cited By ID of the paper, which refers to the root paper, and the last field contains the labels which range from 0 to 3. 0 and 1 indicate the incidental class; 2 and 3 indicate the important class through papers and Cited by IDs. For further processing from ACL anthology, all papers were downloaded manually.

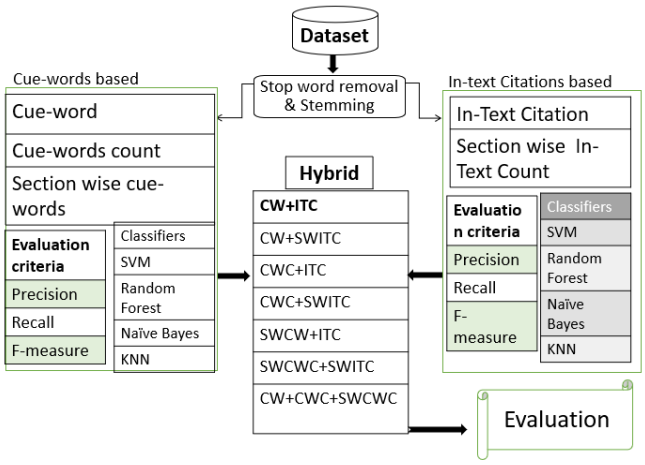


Fig. 1. Context Diagram of Proposed System.

B. Feature Extraction

Our proposed methodology contains a number of different features. Based on these features, we classified citations as important and incidental. Different classifiers were used to evaluate these features: (1) Cue-words based features; (2) In-text based features; and (3) Hybrid (*H* indicates a Hybrid Feature), which includes possible combinations of cue-words based and in-text based features. These features are further subdivided into the following features:

1) Cue-words: In this feature we used Cue-words from the sentences in which citations occur. We picked the sentence where citations appear and one sentence before citations appear and one sentence after citations appear. We collected all citations in the respective paper and counted the words.

2) Cue-words count: In this feature, we used Cue-words count and checked the occurrence of each Cue-word in the whole paper.

3) Section cue-words: In this feature, we used the Cue-words count and checked the occurrence of single Cue-words in each section to identify the importance of that word.

4) In-text citations count: In this feature, In-text Citations were cited by the author to support background knowledge or to extend the previous work within whole paper.

5) Section in-text count: In this feature, we used In-text counts and checked the occurrence on single in-text citations in each section to identify the importance of that citation.

6) Cue-words and in-text count H1: In this feature is the combination of total occurrence of cue-words and in-text citations counted for a respective paper.

7) Cue-words and section in-text count H2: In this feature is the combination of total occurrence of cue-words and Section in-text citations counted for a respective paper to classify citations.

8) Cue-words count and in-text count H3: In this feature is the combination of total occurrence of cue-words count and in-text citations count for a respective paper to classify citations.

9) Cue-words count and section in-text count H4: In this feature is the combination of total occurrence of cue-words count and Section in-text citations count for a respective paper to classify citations.

10)Section cue-words and in-text count H5: In this feature is the combination of total occurrence of section cue-words count, and in-text citations count for a respective paper to classify citations.

11)Section cue-words and section in-text count H6: In this feature is the combination of total occurrence of Cue-words, Cue-words count and section cue-words count for a respective paper to classify citations.

12)Cue-words and cue-words count and section cue-words H7: In this feature cue-words based and in-text citations-based features were used to create all possible combinations.

C. Model Selection

In the literature survey, different authors used different classifiers to classify citations. Each classifier performed according to their functionality and classification system. Our focus was to evaluate which classifier performed better using our proposed approach. The classifiers are as follows:

- SVM.
- RF.
- Naive Bayes (NB).
- KNN.

D. Model Training and Testing

The evaluation criteria used for this research thesis is precision, recall and f-measure. These are widely used to evaluate results for classifying citations into important and incidental classes. For training and testing of citation classification, in this thesis, we are classifying citation using Python; we used four different classifiers with the Scikit learn library for citation classification, and we used the Seaborn Library for graph plots. We categorized datasets based on training models to classify citations into two categories. The dataset of citations, which categorize whether it belongs to the important or incidental class. The returns values of precision recall and f-measure. We evaluated the performance of each classifier on cue-words based, in-text citations based, and Hybrid features. A detailed evaluation of each feature using different classifiers will be discussed in the evaluation step.

IV. Experimental Results and Discussion

A. Experimental Setup

The data set collected for this research work was the most authentic and publicly updated available from [7]. It was published for the AAAI workshop. In the dataset, the author classified citations into two broad categories: important and non-important. The dataset contained 465 citations to be classified in the above-mentioned categories. In the results, 14% citations obtained were important and 86% citations were non-important. We downloaded 416 papers and 49 papers manually from the ACL anthology that were missed in the ACL. The new dataset of 416 is maintained for further processing**.**

B. Performance

In the previous chapters, the literature review discussed the importance of citation classification. Different authors describe different ways of classifying citations. Different authors do not agree upon treating all citations equally and describe the importance of citations in sections, citations in introductions, and related work that belongs to incidental class. Citations that appear in methodology and results are marked as important class. We have collected a dataset of 416 papers by downloading it from the ACL anthology. Approximately 21,500 words were extracted from the dataset to classify citations. 14000 words were marked as incidental and 7500 words were marked as important. Then preprocessing is applied on the collected words, Onix Text Retrieval Toolkit stop word List apply for stop word removal from collected dataset and suffix-stripping algorithm used for stem words in their root form. We removed duplicate words from the data which were generated after the stop word and stemming were applied. A total of 858 unique words were found. Two different files were created. One file contains 631 unique words marked as incidental class and another file contains 227 unique words marked as important class. Then the dataset is ready for applying experiments on it. We classified citation into two broad categories: important and incidental, with the help of cue-words based and in-text based features. We used Python to classify citations. In Python, each feature is selected manually, and different sets of classifiers apply to each feature and generate results against experiments. Classifying citations into important and incidental experiments was performed on Python with the following classifiers: “RF,” “Naive Bayes,” “KNN,” and ”SVM” applied to all possible combinations of features.

C. Features

1) Cue-words based features: In this feature, we concentrated on evaluating the total occurrence of cue-words only to classify citations. In this feature, we will use only the distinct cue-words attained from citations context and associate them with both important and incidental classes. In the cue-words count feature we concentrated on evaluating the total occurrence of cue-words in the paper. In the section cue-words feature, we evaluate the total occurrences of cue-words along with the section in which these cue-words appeared. In this feature, we will use both cue-words and their occurrences in each section.

2) In-text citation-based features: In this feature, we concentrated on evaluating the total occurrence of in-text citation counts alone to classify citations. In this feature, we will use only the count of a specific in-text citation. In the section cue-word, we concentrated on evaluating the total occurrence of section citation counts to classify citations. Here we will use the count of citations presented in logical sections of research papers.

3) Hybrid features: In this section, we are interested in evaluating the strength of cue-words and in-text citations, along with the sections and total number of occurrences, to classify citations. In this feature, we will use all possible combinations of cue-words based features and in-text citations-based features together to classify citations.

D. Classifier and Results

In this thesis we are interested in classifying citations; the classifiers used in this work are commonly used in the research community. The following are the classifiers we used for this research work:

1) SVM: Support vector machines (SVM) are a particularly influential and flexible class of supervised algorithms for both regression and classification. The SVM classifier is mostly used in the literature for classifications. The SVM classification report was generated against hybrid features of cue-words based and in-text citations-based features as shown in Fig. 2. A total of 858 citations were

classified into two broad categories: important and incidental. The 629 citations that belong to the incidental class achieved precision 0.96, recall 0.94 and f1-score 0.97. The remaining 228 citations belonging to the important class achieved precision 0.97, recall 0.99 and f1-score 0.95. This is the best result achieved with the help of the SVM classifier using hybrid features as shown in Fig. 3.

This line chart evaluates the result of using hybrid features as shown in Fig. 4. We used the SVM classifier with evaluation criteria precision, recall and f-measure. In the Predicted Label figure, the blue line indicates incidental class and achieved a result against SVM on precision 0.96, recall 0.94, and f-measure 0.97. In the Predicted Label figure, the orange line indicates the important class result and achieved precision 0.97, recall 0.99, and f-measure 0.95 against SVM.

2) Random forest: Random Forest (RF) is one of the most popular and widely used machine learning algorithms. This classification report was generated against hybrid features of cue-words based and in-text citations-based features. The total 858 citations were classified into two broad categories: important and incidental. The 629 citations that belong to the incidental class achieved precision 0.93, recall 0.99, and f1-score 0.96. The remaining 228 citations belong to the important class and achieved precision 0.96, recall 0.90, and f1-score 0.92. This is the best result achieved with the help of the RF classifier using hybrid features as shown in Fig. 5 and 6.

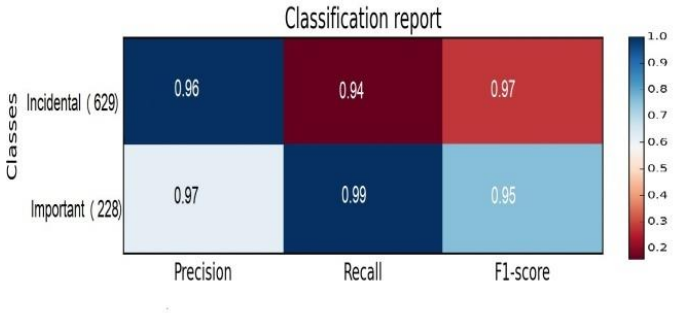


Fig. 2. Classification Report.

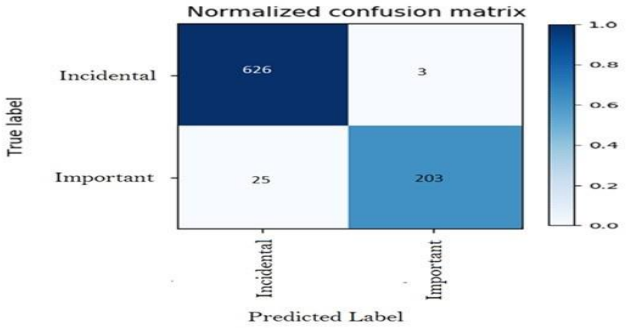


Fig. 3. Confusion Matrix.

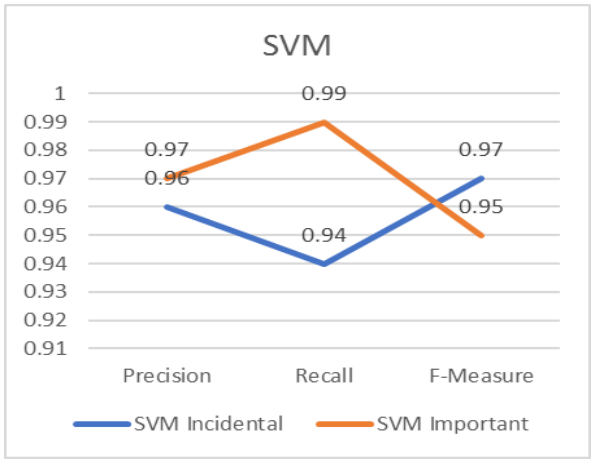


Fig. 4. Line Chart.

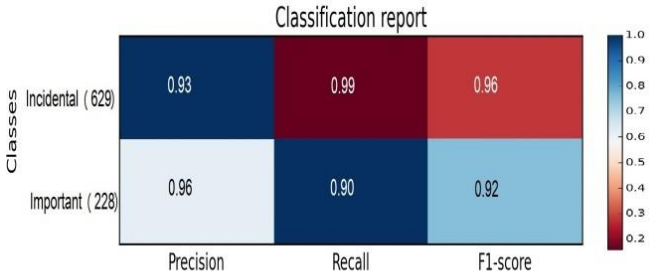


Fig. 5. Classification Report.

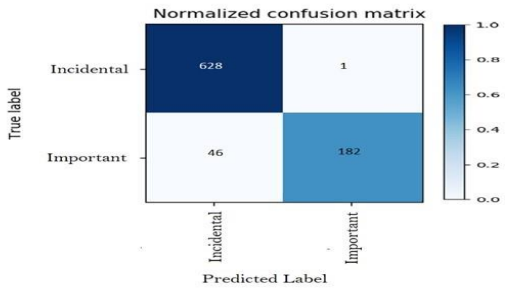


Fig. 6. Confusion Matrix.

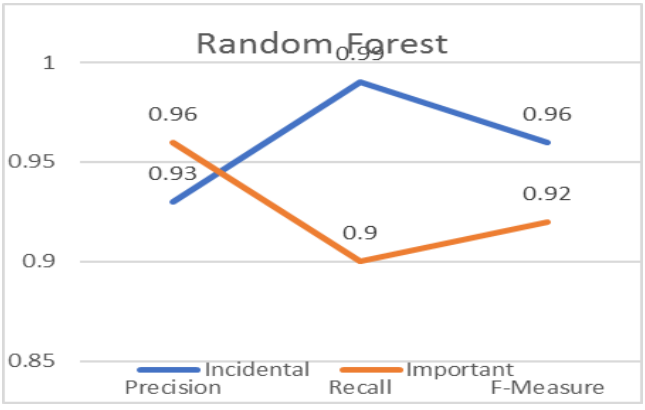


Fig. 7. Line Chart.

In this chart we evaluated the result against hybrid features using the RM classifier with evaluation criteria precision, recall and f-measure as shown in Fig. 7. In the figure, the blue line indicates incidental class results achieved against RM on precision 0.93, recall 0.99, and f-measure 0.96. In the figure, the orange line indicates important class results achieved against RM on precision 0.96, recall 0.90, and f-measure 0.92.

3) Naive bayes: Naive Bayes models are a set of supervised learning algorithms, Naive Bayes learners and classifiers can be exceptionally quick as compared to other sophisticated models. The Naive Bayes classifier was generated against hybrid features of cue-words based and in-text citations-based features as shown in Fig. 8. The total 858 citations were classified into two broad categories: important and incidental. The 629 citations that belonged to the incidental class achieved precision 0.93, recall 0.94, and f1-score 0.94. The remaining 228 citations belong to the important class and achieved precision 0.90, recall 0.88, and f1-score 0.89. This is the best result achieved with the help of the NB classifier using hybrid features.

In this chart, we evaluated the result against hybrid features using the NB classifier with evaluation criteria precision, recall and f-measure as shown in Fig. 9. In the figure, the blue line indicates incidental class result achieved against NB on precision 0.93, recall 0.94, and f-measure 0.94. The orange line indicates important class results achieved against NB at precision 0.90, recall 0.88, and f-measure 0.89.

4) KNN: K Nearest Neighbor (KNN) is a very simple, straightforward, adaptable and one of the topmost machine learning algorithms. The KNN classifier was generated against hybrid features of cue-words based and in-text citations-based features. The total 858 citations were classified into two broad categories: important and incidental as shown in Fig. 10 and 11. The 629 citations that belong to the incidental class achieved precision 0.93, recall 0.94, and f1-score 0.93. The remaining 228 citations belong to the important class and achieved precision 0.88, recall 0.86, and f1-score 0.87. This is the best result achieved with the help of the KNN classifier using hybrid features.

In this chart we evaluated the result against hybrid features using the KNN classifier with evaluation criteria precision, recall and f-measure as shown in Fig. 12. In the figure, the blue line which indicates an incidental class result, achieved precision 0.93, recall 0.94, and f-measure 0.93 against KNN. In the figure, the orange line indicates the important class result achieved precision 0.88, recall 0.86, and f-measure 0.87 against KNN.

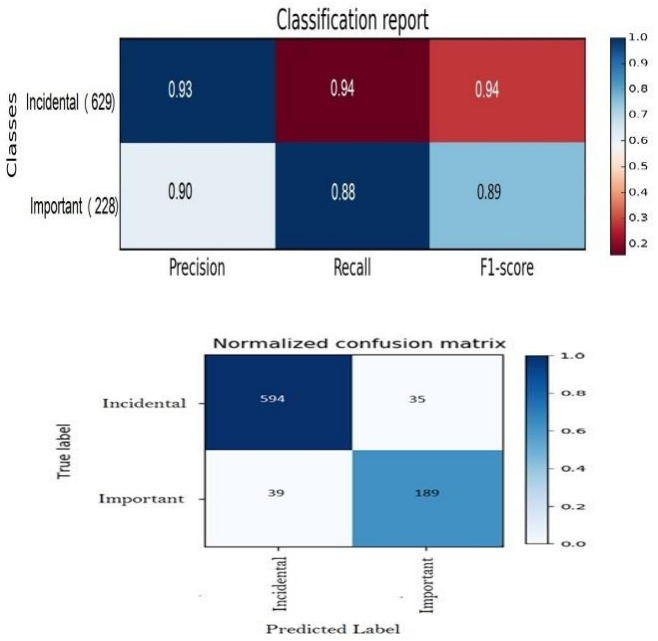


Fig. 8. Confusion Matrix.

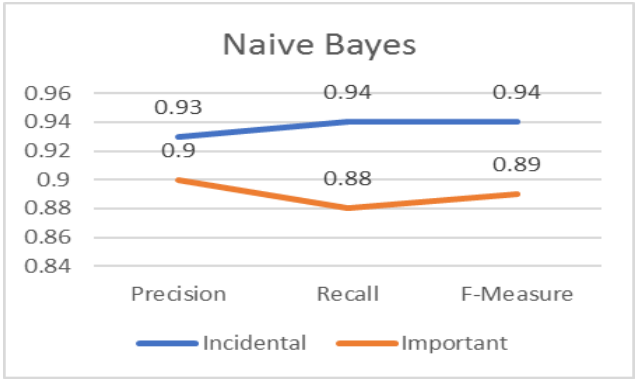


Fig. 9. Line Chart.

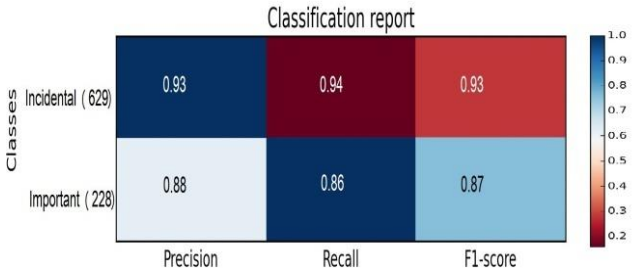


Fig. 10. Classification Report.

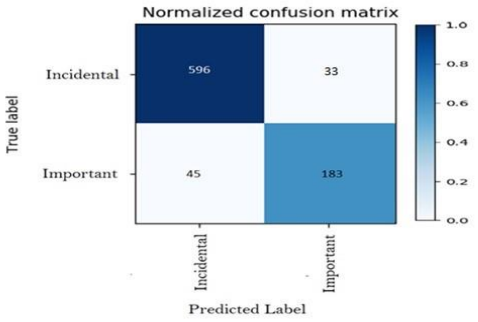


Fig. 11. Confusion Matrix.

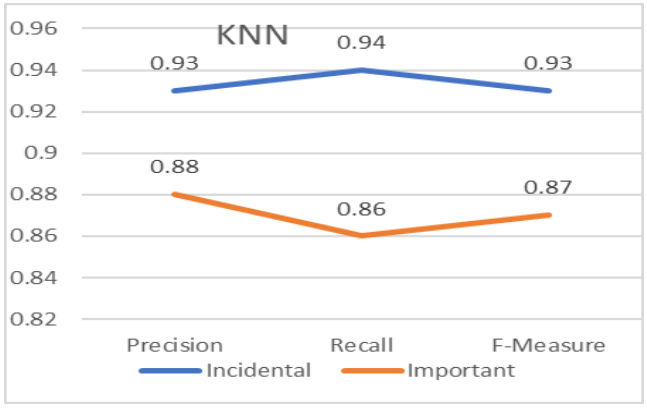
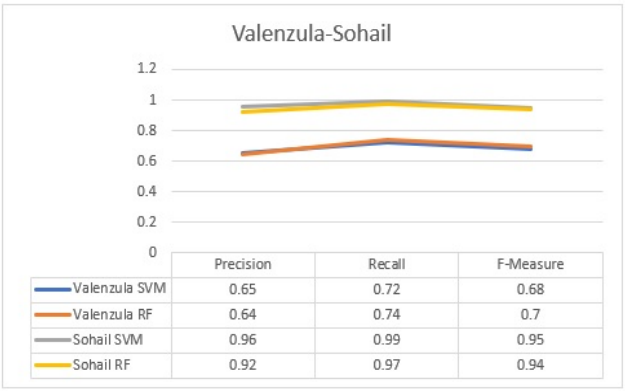


Fig. 12. Line Chart.



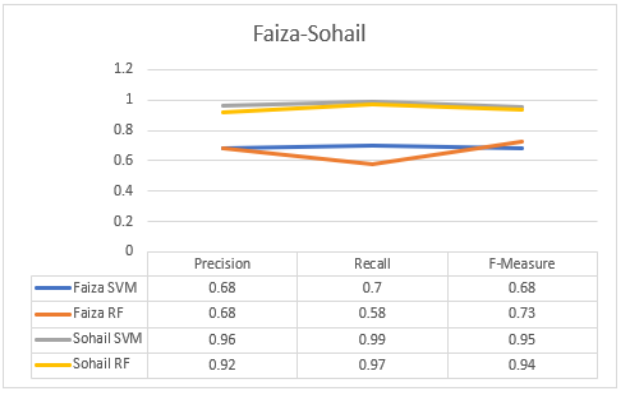


Fig. 13. Comperison with Existing Approaches.

V. Comparison

In this section we compared of our approach generated results with the results of existing approaches by the research community, with same domains that use the same classifiers such as SVM and RF.

1) Valenzuela's: dataset is used in most of the articles. Valenzuela claimed that she is the first to in the research community to identify two broad categories for citation: important vs. incidental. Most of the approaches used different classifiers with Random Forest and Support Vector Machine being the most common classifier used in all the approaches as shown in Fig. 13.

2) Faiza: proposed classifying binary citation technique. This scheme is based on metadata and content-based parameters to classify citation. Faiza was first to classify citation as important vs. non-important using a permanent metadata-based hybrid. Features used to classify important vs. non-important citation included two different types: of parameter: metadata based and content-based. She used these classifiers to classify citations with precision achieved on SVM 0.68, KLR 0.62, and RF 0.72, Recall on SVM 0.7, KLR 0.59 and RF 0.69 and f-measure on SVM 0.68, KLR 0.58 and RF 0.73.

In this section we compare our results of classifying citations with Valenzuela et al. and Faiza et al.'s existing approaches in the research community with the same domain as shown in Fig. 13. We used four classifiers to classify citations: SVM (Support Vector Machine) and Random Forest (RF) are most commonly used classifiers and compare with other approaches. The average SVM accuracy achieved precision 0.96, recall 0.99, and f-measure 0.95, and RF accuracy achieved Precision 0.92, recall 0.97, and f-measure 0.94 as the best result.

VI. Conclusion and Future Work

Citations are essential in the scientific community to assess the qualifications of the scientific authors. It is imperative in many situations because we must take direction from them in their subject. We proposed methodology to comprehensively compute all possible combination of cue-words based and in-text based features for classifying citations. We used the publicly available Valenzuela dataset as a benchmark and we used Scholarly Big data for experiments published in the AAAI workshop. We performed preprocessing on the collected dataset, applying the stemming and stop words removal algorithm. After preprocessing we removed duplicate words so that the remaining list of unique words totaled 858. Among these, 629 are incidental and 229 are important citations. When

the collected dataset was ready for experiment and evaluation, it was performed using Python. Our features are categorized into three main categories: (1) Cue-words based features; (2) In-text based features; and (3) Hybrid where all possible combinations of cue-words based and in-text based features were examined. These features are further subdivided. We evaluated all possible combinations of features and used five different classifiers: SVM, RF, Naive Bayes, and KNN. Each classifier performance was different for each feature. In the hybrid approach, all feature performances were better in SVM, and RF performed better than others. At the end, we made a grand comparison of results for our approach to classifying citation with the existing approaches by the research community in same domain. The average SVM accuracy achieved was precision 0.93, recall 0.99, and f-measure 0.96; for RF, accuracy is precision 0.97, recall 0.99, and f-measure 0.92, Naive Bayes accuracy achieved precision 0.90, recall 0.94, and f-measure 0.92, and average KNN accuracy achieved precision 0.93, recall 0.90, and f-measure 0.90, which are the best results as compared with other approaches.

VII. Future Work

In this research work our focus was identifying important and incidental citation and comparing techniques. This is the publicly available dataset for this domain. To ensure the accuracy of the technique, studies must be performed on other domain as well with large datasets to ensure the validity of the technique.

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Analysis of Accuracy and Precision of WLAN Position Estimation System based on RSS

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***Abstract*—The coordinates of the position of a wireless access point are the main goal in the wireless localization technique. In common, outdoor wireless localization techniques use the trilateration method by installing several devices used as anchors, and this makes the cost for installation and maintenance higher. An outdoor wireless localization system that is more efficient, effective, and flexible but still accurate and precise becomes indispensable. This paper proposes a wireless position estimation system based on a received signal strength (RSS) value called WLAN Position Estimation System (WLAN PES) integrating WLAN Distance Estimation System (WLAN DES) with WLAN PES formula. To confirm the accuracy and precision of WLAN PES, this paper focuses on the analysis of WLAN PES testing conducted at ten points in which each measurement point had coordinates and angles that are different from one another. The test point was made to circle the target WLAN access point. The distance of each test point was 1000 meters against the targeted WLAN access point. In each of these test points, the WLAN finder reads RSS_{fnd}. Then, the system calculated the estimated distance value using WLAN DES based on the RSS_{fnd} value. After the system obtained a distance estimation value, the estimated position value was calculated with the WLAN PES formula. In addition to the distance estimation value, WLAN PES formula required some variables such as latitude and longitude coordinates from the WLAN finder position, and the bearing of the WLAN finder. WLAN PES was found to be capable of determining the estimated position coordinates of a WLAN access point with an accuracy value and precision value of 93.26% and 98.77%, respectively.**

***Keywords*—WLAN position estimation system; WLAN distance estimation system; accuracy and precision wireless localization; efficient and flexible outdoor wireless localization**

I. Introduction

Frequency is a limited resource. The use of outdoor 2.4 GHz WLAN is proliferating for both point-to-point and point-to-multipoint purposes. The limited 2.4 GHz WLAN channel and the increasing use of 2.4 GHz WLAN, especially those installed outdoor, can cause high levels of interference. This, later on, makes the WLAN users to use a range of frequency channels prohibited by government regulations. Hence, monitoring techniques, mitigation techniques, and localization techniques for using WLAN are needed for the optimal and adequate use of frequency resources. Some wireless localization studies in indoor use areas [1]–[3]and use network-based positioning techniques [4], [5], then several other studies on outdoor wireless localization are based on trilateration or triangulation methods [6], [7].

This method requires several anchors; as a consequence, it becomes less flexible and less efficient in providing devices. In several studies, wireless localization techniques are generally used to localize mobile devices such as smartphones and other tracking devices. Fingerprint method is frequently used in localization and it can be categorized into three types: visual fingerprint, motion fingerprint, and received signal strength (RSS) fingerprint [8]–[10]. Localization with RSS fingerprint method processed based on regression can be accurately used to reduce position estimation errors [11], [12].

In this paper, we discuss the outdoor wireless localization technique for finding the position coordinates of WLAN access points in base transceiver station efficiently and effectively but still accurately and precisely. The position estimation system in this paper is called WLAN Position Estimation System (WLAN PES). This paper focuses on testing the accuracy and precision of WLAN PES.

II. WLAN Distance Estimation System

The distance value is significant in the outdoor wireless localization. Before determining the position, a system that can determine the distance estimation is needed. The developed system and part of the position estimation system in this paper are called WLAN Distance Estimation System (WLAN DES). This system integrates outdoor wireless fingerprinting techniques, data analysis systems, and regression analysis. Fig. 1 illustrates the chart of WLAN DES.

The empirical data collection technique in WLAN DES used the outdoor wireless fingerprinting method. The empirical data consists of the received signal strength of the target WLAN access point received by the WLAN finder (RSS_{fnd}) and the real distance between the WLAN finder and the WLAN access point (D_{real}) [13]. Data from outdoor wireless fingerprinting was analyzed and regressed with a third-degree polynomial to obtain the WLAN DES formula [14].

WLAN DES formula was used to calculate the value of the estimated distance (D_{est}) between a WLAN finder and a WLAN access point based on the RSS_{fnd} value received by the WLAN finder Equation (1) refers a formula to calculate the distance estimation of a WLAN access point in the range 0-8000 meters.

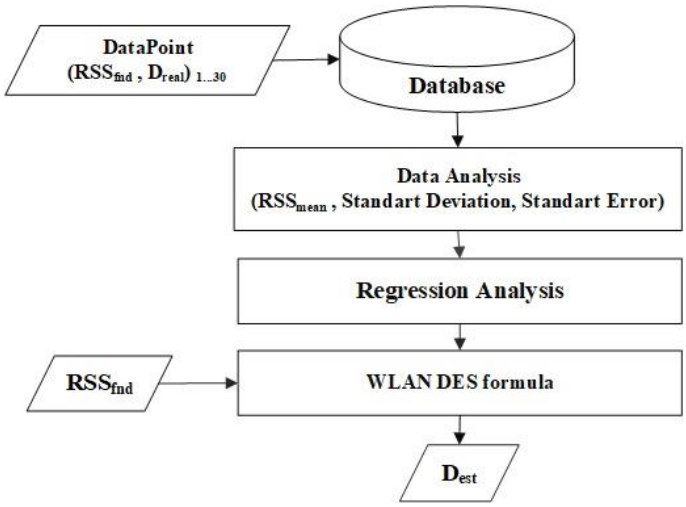

Fig. 1. WLAN Distance Estimation System.

$$D_{est} = -0{,}0062RSS_{fnd}{}^3 - 0{,}5455RSS_{fnd}{}^2 - 17{,}95RSS_{fnd} - 132{,}94 \quad (1)$$

III. WLAN Position Estimation System

WLAN PES combined the WLAN DES and a geodetic system to determine the coordinates of the position of a target WLAN access point. Fig. 2 shows the algorithm of WLAN PES.

The system was initialized by placing a WLAN finder in a position with specific coordinates. The WLAN finder scanned RSS_{fnd} from WLAN access points with target frequency channels by rotating the antenna until finding the highest $RSS_{fnd.}$ The direction of the WLAN finder antenna when getting RSS_{fnd} at highest value was converted to bearing angle. The highest RSS_{fnd} value subsequently was converted to distance estimation value using WLAN DES.

WLAN PES consists of 2 main parts:

1) WLAN DES part. This training phase section produces an adaptive WLAN DES formula to calculate the distance estimation value of a WLAN finder against WLAN access point targets.

2) WLAN PES formula also called PEC. The localization phase was used to calculate the estimation of the coordinates of the target WLAN access point position. Three primary data required in the PEC were the estimated distance between the WLAN finder and the WLAN access point target (D_{est}), the bearing angle of the WLAN finder (B_{fnd}) and the position coordinates of the WLAN finder (P_{fnd}).

Fig. 3 presents the WLAN PES algorithm.

Equation (2) is a formula to calculate the estimated latitude of a WLAN access point (Lat_{ap}) [15].

$$Lat_{ap} = \operatorname{asin}\left(\sin(Lat_{fnd}) \times \cos\left(\frac{D_{est}}{R}\right) + \cos(Lat_{fnd}) \times \sin\left(\frac{D_{est}}{R}\right) \times \cos(B_{fnd})\right) \quad (2)$$

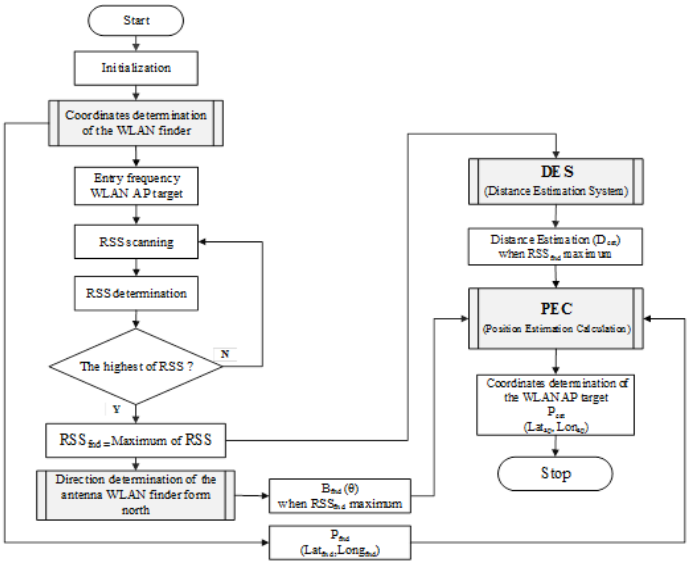

Fig. 2. Algorithm of WLAN Positioning Estimation System.

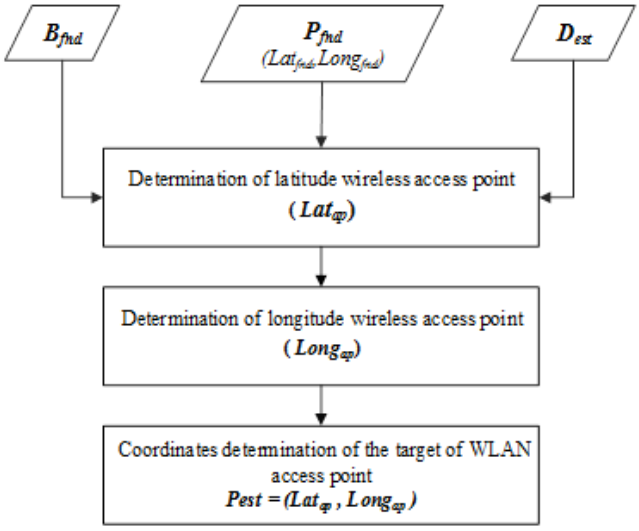

Fig. 3. WLAN PES Formula.

Equation (3) is a formula to calculate the estimated longitude of a WLAN access point. (Lon_{ap}).

$$Lon_{ap} = Lon_{fnd} + \operatorname{atan2}\left(\cos(\frac{D_{est}}{R}) - \sin(Lat_{fnd}), \sin(B_{fnd}) \times \left(\sin\cos(D_{est} \div R) \times \cos(Lat_{fnd})\right)\right) \quad (3)$$

Equation (2) and equation (3) were then combined into the WLAN PES formula as in (4).

$$P_{est} = Lat_{ap}\ ;\ Lon_{ap} \quad (4)$$

IV. Results and Discussion

A. WLAN PES Testing

The WLAN PES testing scheme started by placing a WLAN access point at a location and placing a WLAN finder at ten points in which measurement point had coordinates and

bearings that were different from one to other. The distance of the WLAN finder to the WLAN access point was 1000 meters, and the position of the WLAN finder was made around the WLAN access point, as shown in Fig. 4.

WLAN PES testing was carried out in the position of WLAN finder-1 to WLAN finder-10, as illustrated in Fig. 4. The coordinates of the WLAN finder position were denoted in the form of P_{fnd} (Lat_{fnd}, Lon_{fnd}). There were 30 RSS_{fnd} data from each test point within 30 seconds. To find out the bearing angle of WLAN finder (B_{fnd}) against the WLAN access point was by scanning the maximum RSS_{fnd} value. The maximum RSS_{fnd} value indicated that the direction of the WLAN finder antenna was in the direction of the WLAN access point.

Determining the estimation of the WLAN access point position was started by calculating the latitude of the WLAN access point (Lat_{ap}) and calculating the longitude of the WLAN access point (Lon_{ap}). The reference value (earth radius) was around 6,371,000 meters or 6,371 kilometers. The results of WLAN PES testing are informed in Table I.

B. Summary of WLAN PES Testing

Based on the results of the WLAN PES test as presented in Table I, the mean of distance estimation was performed using the calculation below.

$$D_{est-mean} = \frac{\sum(D_{est-10})}{\sum f_{Dest-10}}$$

$$D_{est-mean} = \frac{(1065+1065+\cdots+1065}{10}$$

$$D_{est-mean} = \frac{10720}{10}$$

$$D_{est-mean} = 1072$$

The mean of the deviation of distance estimation was then calculated. The deviation of distance estimation is the absolute value of the difference between the estimated distance and the mean of distance estimation. The calculation is presented as follows:

$$Dev.From\ mean\ _{mean} = \frac{\sum Dev.From\ mean\ -10}{\sum f-10}$$

$$Dev.From\ mean\ _{mean} = \frac{7+\ldots+7}{10}$$

$$Dev.From\ mean\ _{mean} = \frac{131}{10} = 13.1$$

It was continued to calculate the accuracy and precision of the WLAN PES test with the following calculation:

1) The accuracy

$$accuracy = (1 - \left(\frac{Real\ distance - D_{est-mean}}{D_{est-mean}}\right)) \times 100\%$$

$$accuracy = (1 - \frac{72}{1072}) \times 100\%$$

$$accuracy = 93.26\%$$

2) The precision

$$precision = (1 - \left(\frac{Dev.From\ mean_{mean}}{(D_{est-mean})}\right) \times 100\%$$

$$precision = (1 - \left(\frac{13.1}{1072}\right) \times 100\%$$

$$precision = 98.77\%$$

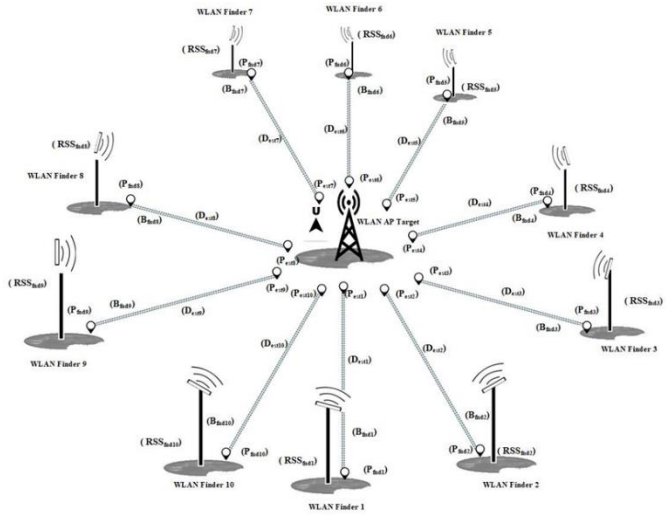

Fig. 4. WLAN PES Testing Scheme.

TABLE. I. RESULTS OF WLAN PES TESTING

No. of Test	D_{real} (m)	RSS_{fnd} (dBm)	B_{fnd} (degree)	D_{est} (m)	P_{fnd}		P_{est}	
					Lat_{fnd}	Lon_{fnd}	Lat_{est}	Lon_{fnd}
1	1000	-46	78°	1065	-7.725350°	110.679662°	-7.723359°	110.689116°
2	1000	-46	60°	1065	-7.727939°	110.680686°	-7.723150°	110.689057°
3	1000	-46	39°	1065	-7.730397°	110.682797°	-7.722954°	110.688880°
4	1000	-46	356°	1065	-7.732406°	110.689223°	-7.721515°	110.688454°
5	1000	-46	303°	1065	-7.728309°	110.696197°	-7.723727°	110.688091°
6	1000	-46	246°	1065	-7.719831°	110.696890°	-7.723766°	110.688090°
7	1000	-46	239°	1065	-7.718833°	110.696375°	-7.723349°	110.688790°
8	1000	-46	220°	1065	-7.716559°	110.694419°	-7.723896°	110.688206°
9	1000	-47	153°	1138	-7.715387°	110.684426°	-7.724506°	110.689115°
10	1000	-46	138°	1065	-7.716737°	110.682446°	-7.723855°	110.688913°

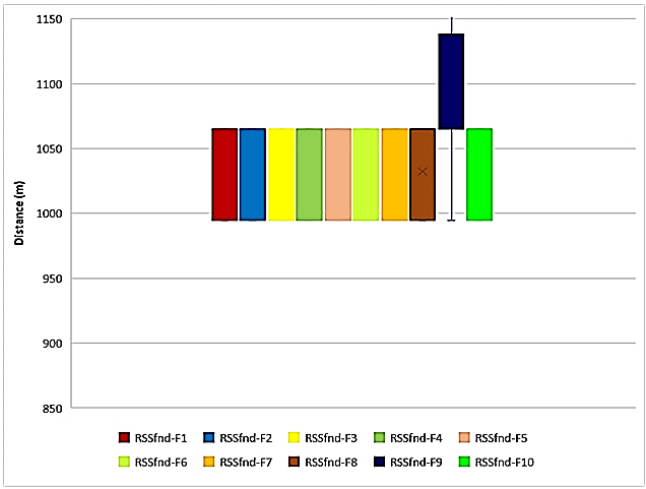

Fig. 5. The Plot Graph of WLAN PES Testing.

The analysis of accuracy and precision from the ten WLAN-PES tests can be visualized into plot graphs, as shown in Fig. 5.

V. Conclusion

The analysis of WLAN PES testing at ten positions over a distance of 1000 meters resulted in the values of accuracy and precision of 93.26% and 98.77%, respectively. It then has proven the capability of WLAN PES to be an outdoor wireless localization system that is efficient, effective, flexible, but still accurate and precise.

WLAN PES is more efficient and effective because, in its application, it only requires one RSS value to be able to estimate the coordinates of a WLAN access point position. It is also flexible for use in various areas without a need to install any additional devices. The WLAN position estimation system simulator will be the topic of future research.

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Metric-based Measurement and Selection for Software Product Quality Assessment: Qualitative Expert Interviews

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***Abstract*—A systematic and efficient measurement process can assist towards the production of quality software product. Metric-based measurement method often used to assess the product quality. Currently several hundreds of metrics have been proposed by previous researchers. However, there is no specific and structured mechanism for metrics selection process. Lack of awareness, knowledge and experience lead to selecting inappropriate and unsuitable metrics for assessment of software product quality done by the practitioners and stakeholders in the industry. Literature study found that the existing selection models are irrelevant and insufficient for assisting and supporting metrics selection process in which it should consists of criteria, and systematic and practical methods of selection process. A qualitative interview was conducted involving 12 experts and practitioners to reveal current issues in software measurement, to identify elements relevant for software metric selection process and to identify the appropriate and valid software metric selection criteria. Finding from this expert interview revealed important input from industry which are: Five main issues in software measurement, six elements associated with metric selection process and 13 criteria relevant for software metric selection.**

***Keywords*—Software product metric; metric selection criteria; software quality; software measurement; selection process; qualitative study**

I. Introduction

Systematic measurement is an important procedure to ensure and maintain the quality attributes of product deliverables to customers or users. Making the measurement process works in organisation requires collecting correct and relevant metrics based on organisation's objectives and goal. In order to obtain metrics and measurements that address the needs of organizations, the measurement process must be structured, systematic and guided. Software measurement based on quality model and software metric has been introduced and investigated by previous researchers such as Fernando Pinciroli, Yahaya & Aziz, Bouwers, Deursen & Visser, and Ahmad Fadzlah & Deraman [1][2][3][4]. Current and available quality models developed by previous researchers offered general and imprecise criteria for software quality assessment [2][5][6][7].

Software metrics is a measure of software characteristics, which are measurable or countable. Software metrics is "an objective, mathematical measure of software that is sensitive to differences in software characteristics. It provides a quantitative measure of an attribute which the body of software exhibits" [8]. There are many studies that proposed different types of metrics such as security metrics [9], usability metrics [4], and web application metrics [10][11]. Software metrics will affect the measurement program and eliminating inaccurate metrics will improve software performance and reduce wastage[10]. However, there is no consensus on which metrics are relevant and worth for selection [2][5][12][13].

A number of previous researches [14][15][16] stated use of standards as a success factor in metric selection (e.g. ISO/IEC 15939 [17], ISO/IEC 9126[18], ISO/IEC 25000 [19] and ISO/IEC 14598 [20]). However, there is still no consensus in the software measurement area on which standard(s) to use. Most standards present only quality metrics or basic project management metrics such as size (Function Points, cyclomatic complexity etc.).

Studies have revealed that after the second year of implementing measurement metrics, 50%-80% of these measurements are not maintained [14][15]. It is also found that a very high failure rate in metric implementation which is 66.7%. Even though software metric has been introduced by previous researchers, managing and maintaining the assessment program is a challenge and mostly because of lack of commitment from staff [16], no guideline for implementation [17], lack of experts [15] and also there is no metric repository for effective and efficient metric selection to the practitioners and stakeholders [2][5][12].

This paper presents the qualitative expert interviews and findings on software product quality assessment based on metric-based measurement from industrial perspectives. It starts the discussion with background and related work in Section 2, and continues with the qualitative interview in Section 3. Section 4 discusses the analysis and findings, and Section 5 presents the result and discussion. This paper concludes with a conclusion in Section 6.

II. Background and Related Works

This section discusses the current issues, challenges, concepts and related works regarding metric-based measurement and selections.

A. Software Quality Models

Literature study has revealed several quality models available to measure and assess software product quality such models are: McCall [21], Boehm [22], FURPS [23], ISO 9126 [18], ISO 25010 [19], Pragmatic Quality Factor or PQF [24]. Current user's requirements and expectation demand for

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software quality model that is easy, accurate and practical to use not only for the developers and practitioners but also to be used by the users, customers and stakeholders [12].

McCall model is among the earliest software quality model and is known as factor criteria metric [25]. It consists of integration of 11 factors and 23 criteria for software product quality. The main contribution of this model is the relationship between quality characteristic and metrics even though there is a claim saying that not all metrics are objective to be measured. Boehm model was developed based on McCall with additional characteristics which cater for maintenance and system utility.

ISO/IEC 9126 is a well-known software quality model aims for quality standardisation of software product. ISO/IEC 9126 defines quality in six main characteristics which are functionality, reliability, usability, efficiency, maintainability and portability. These characteristics are further broken down into sub characteristics [3] [18]. It has been invented since 1991 and today, it is still being used in researchers that work with software product quality. However, at the same time it has the disadvantage of not showing clearly how these quality characteristics can be measured and the model only focusing on developer view of the software [3]. In 2011, ISO/IEC 9126 was reviewed and a new international standard was introduced for software product quality assessment, ISO/IEC 25000 (System and Software Quality Requirements and Evaluation or SQuaRE). ISO/IEC 25000 is the result of the evolution of several other standards; specifically, from ISO/IEC 9126, which defines a quality model for software product evaluation and assessment. The product quality model defined in ISO/IEC 25010 comprises the eight quality characteristics which are Functional Suitability, Performance efficiency, Compatibility, Usability, Reliability, Security, Maintainability, and Portability [19] as listed in Table I. This standard defines a product quality model composed of characteristics (which are further subdivided into sub characteristics) that relate to static properties of software.

Later model of software quality is called Pragmatic Quality Factor or PQF. It was developed based on ISO 9126 model and added two more attributes: integrity and impact [3]. This model divides attributes into two main classifications which are behavioural attribute and impact attributes. The attributes are broken down into several sub attributes and metrics. PQF defines behavioural attribute that comprises of usability, efficiency, functionality, maintainability, reliability, portability and integrity. While the impact attribute comprises of user perception and user requirement. This model has included user factors and these characteristics were not included in previous models. User factors are considered essential and important since user nowadays are more demanded and recognised for good quality software and thus relevant to their perspectives for quality. Different users may have different perspective and requirement toward quality product. Therefore, in PQF model comprises of weight value for each of the quality characteristics to represent individual and organisational need on quality measurement and assessment [3].

TABLE I. ISO25010 QUALITY MODEL: SOFTWARE PRODUCT QUALITY [19]

Characteristic	Sub Characteristic
Functional Suitability	• Functional Completeness • Functional Correctness • Functional Appropriateness
Performance Efficiency	• Time Behaviour • Resource Utilization • Capacity
Compatibility	• Co-existence • Interoperability
Usability	• Appropriateness Recognisability • Learnability • Operability • User Error Protection • User Interface Aesthetics • Accessibility
Reliability	• Maturity • Availability • Fault Tolerance • Recoverability
Security	• Confidentiality • Integrity • Non-Repudiation • Accountability • Authenticity
Maintainability	• Modularity • Reusability • Analysability • Modifiability • Testability
Portability	• Adaptability • Installability • Replaceability

B. Software Measurement

Measurement is essential and important in everyday life as well as in scientific and engineering discipline. Measurement is the assignment of a number to a characteristic of an object or event, which can be compared with other objects or events [26]. It cannot be done if the underlying measures are not objective but rather subjective.

The main objective of software development in organisation is to produce good quality software products. Measurement can be used to measure or assist in measuring the product quality. Without measurement, assessment and evaluation are considered as subjective matter and unable to compute and compare. Metrics or measures provide indirect measuring towards software quality [27] and enable the quality to be quantifiable and countable [28].

Software metrics are important for many reasons, including measuring software performance, planning work items, measuring productivity, and many other uses. In this case, metrics are used to measure characteristics or attributes of software product [3]. Using certain rules will illustrate meaning and guidance regarding software's characteristics and behaviour. Mostly all quality model discussed in this paper are embedded with measurements and metrics to quantify and assess software product quality. As an example:

Attribute: Functionality
Sub attributes -> {metrics}
Sub attribute1:
Accuracy -> {M1, M2, M3}
Accuracy -> {M1=Incomplete result, M2=Incorrect result. M3=Unexpected results issued}
Sub attribute2:
Interoperability-> {M4, M5}
Interoperability-> {M4=Data format, M5=Data exchange}
Sub attribute3:
Suitability-> {M6, M7, M8, M9}
Suitability -> {M6=Functional Implementation coverage; M7=Functional specification stability; M8=Functional implementation correctness; M9=Functional implementation completeness}

The structure of this hierarchy (the attribute, sub attribute and metrics) is shown in Fig. 1.

The decomposition of sub attributes is at Second Level of this hierarchy. Functionality is considered as unmeasurable characteristic and thus involves indirect measurement. In order to convert the unmeasurable characteristic to a measurable characteristic, sub attributes of functionality are decomposed into lower level of hierarchy which is the third level. At the third level, the sub attributes are decomposed into metrics which are used to measures software product quality.

Various software metrics have been proposed by previous researchers to support assessment of software product quality and also to predict quality and other maintenance activities [29][30][31]. However, the emergent of various metrics has introduced new challenge to the practitioners and stakeholders in order to select and use the appropriate metric that meet organisational goal and objectives. Some metrics are too complex and difficult to understand and use [5][13][32].

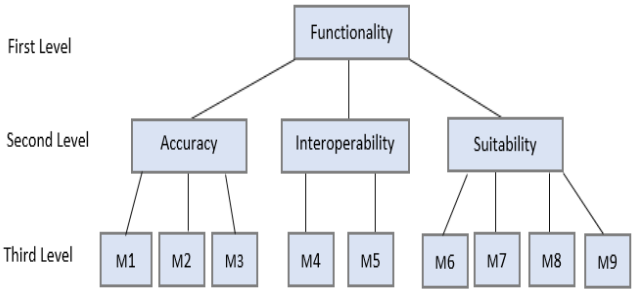

Fig. 1. Structure of Decomposition and Hierarchy.

Literature study has identified previous studies which focused and proposed specific criteria for metric selection. Such criteria are measurement theory [33][34], IEEE standard [35], Kaner Framework [36] and search-based approach[37]. Most of the criteria are applicable for internal measurement. However, studies have shown that software that meet and fulfil the internal measurement criteria do not guaranteed the successful and effectiveness of the software from user's perspective[38][39]. In order to ensure the quality of the software, measurement from external view that focuses on user acceptance and satisfaction are also required [5][11][12]. Previous studies have revealed that user acceptance and satisfaction are the main factors to foresee the successful of software product [40][41].

Our study focuses on external measurement based on software metrics as the scope of this study. We do not cover the internal metrics for internal measurement as discuss in this section.

C. Issues and Challenges in Software Measurement

Software evolution has seen the emergent of different types of software for different purposes. Nowadays, software has become very important in everyday life of everyone and thus the quality of the software is also an essential issue to be highlighted and focused. Even though several software quality models have been introduced and developed such as McCall, Boehm, ISO9126, PQF and ISO25010 as discussed in this paper, but the implementation of measures and metrics were not being mentioned and discussed in detail. A good measurement program has appropriate and relevant measurement metrics [10], comprehensive data collected [42], and consistent with the organisational goal [43]. Several issues are still underpinning in this matters.

1) Lack of commitment: The benefits and advantages for measurement program must be explained and accepted throughout the organisation. Without commitment from the organisation top level and staff, it is difficult to obtain accurate and up-to-date data on measurements. This also links with the commitment from top management to support the measurement program [43]. Thus, only relevant and appropriate software measurement metrics will be collected to ensure the organisational goal is achieved.

2) Absence of guideline and standard: The information, communication and technology strategy was developed during the planning phase for identifying the requirements and specification for ICT implementation. The ICT framework and strategy have been revised accordingly based on new additional and modified requirements. Current measurement process and program do not provide the mechanism for maintaining the measurement framework for organisations [32]. Therefore, there is a requirement to have the guideline and mechanism to support the organisation's software measurement and assessment program to support ICT strategy and organisation's goal.

3) Limited of expert resources: Literature study revealed that one of the reasons for failing in software measurement was due to limited expert in selecting metrics relevant and

appropriate with organisational strategy and goal [44]. Limitation in expert resources may be because of lack of graduate with knowledge or experience in software measurement area. The measurement topic and subject are only offered for graduate study and not during undergraduate study [44].

4) Limited measurement metric resources: Previous works proposed several numbers of metrics for software measurement and assessment but the application and implementation of these metrics in real environment is ambiguous without systematic guideline of the usage [2][12][45]. There is no guideline for metric selection based on organisational strategy and goal. Thus, there is requirement to gather all the metrics with associated mechanism to guide in the implementation and application. This will encourage reusable of metrics in similar purposes and goals.

III. Qualitative Expert Interview

The objectives of this study were to identify current practices and issues related to software metric and measurement, to identify elements needed for software metric selection process, and to identify software metrics selection criteria from real industrial input.

A. The Protocol Design

The interview protocol was designed based on qualitative approach and divided into three parts as follows:

1) Part I: Introduction to Metric: This part is to discover information regarding the implementation and the use of metric in software development and assessment. It consists of eight questions in related to software metric practices, the importance of software metric and success factors for metric implementation. The questions are:-

- What is your opinion regarding software metric?
- What are the examples of software metrics that you use during software development?
- How would software metrics benefit to software development activity?
- In what way metric is used during software development?
- Software development involves several phases. In which phase the metrics can be used and applied?
- There are a few software metrics currently available such as line of code (LOC), cyclomatic complexity (CK), Halstead metrics, fog index and fin-in/fan-out metric. Do you use these metrics during software development or assessment?
- If No (for question (f)), why?
- What are the factors that influence of not using software metrics during development and assessment process?

2) Part II the elements: This part of the interview protocol requires to investigate the elements needed in software metric evaluation and selection process. It consists of eight questions associated with criteria for metric selection.

- Who will use software metrics in your department/organisation?
- What is the technique used for metric assessment and selection?
- Is there necessary to have standard in software metric selection?
- What is the method used to collect data regarding assessment goal setting in your department/organisation?
- What is the synthesis technique used during metric selection process to measure the appropriateness of the metric?
- Do you think that each metric should be assigned with appropriate suitability level?
- Is there any list of software metric for Malaysian Public Sector?
- Is there any metric selection repository to be used among public sector organisation?

3) Part III software metric selection criteria: Part III consists of three main questions related to components and techniques in software metric evaluation and selection. Previous studies have proposed and suggested numerous metrics for software assessment and evaluation. At the same time, the issue arises: how to evaluate and select appropriate metric based on organisation's requirements? The questions asked in this part of the protocol include:

- In literature study, we discovered several criteria or characteristics for metric evaluation. In your opinion, what are the appropriate criteria for evaluating software metric in the industry?
- How would these criteria and characteristic be used in metric evaluation process?
- Can you think of any other suitable criteria for metric evaluation?

This study has invited two senior university academicians to involve and participate as pilot study. They are chosen based on their expertise in software engineering and qualitative method. The academic experts played as a role to review and validate the protocol. The protocol which consists of questions as mentioned as Part I, Part II and Part III were corrected and refined before the actual interviews were conducted.

B. The Sampling

This study was carried out through series of interviews with 12 selected expert informants. The selection criteria of informants are based on expertise in software engineering and more specific in evaluation, measurement and testing. The

duration of working experience also considered as selection criteria where at least they have working experience more than five years in the industry. The duration of working experience for the informants is based on the years suggested by [46]. Table II shows the informant's background who involve in this interview. Majority of the informants have working experience more than 10 years in the industry. 83% of the informants are working in public sector and 17 % are working in private sector. In this paper, the informants are labelled as A, B, C, D, E, F, G, H, I, J, K and L respectively.

In this qualitative study, we found it was hard to find informant or people who have knowledge directly on software metric either in public or private sector. Thus, the informants were selected based on their experience in software evaluation and software metric throughout their working experience. Most of the informants are from public sector because the scope of this study is in public sector.

TABLE II. INFORMANT'S BACKGROUND

Informant	Job Description	Expertise	Years of Working Experience	Sector
A	Researcher	Software Evaluation	>20 years	Public
B	Researcher	Software Evaluation	>30 years	Public
C	Researcher	Software Project Management	>15 years	Public
D	Researcher	Software Evaluation	>15 years	Public
E	Researcher	Software Metric	>20 years	Public
F	Researcher	Software Metric	>30 years	Public
G	Software Engineer	Software Testing	>5 years	Semi-Government
H	Software Development Manager	Software Evaluation	>15 years	Private
I	Software Development Manager	Software Evaluation	>20 years	Private
J	Project Manager	Software Testing	>20 years	Public
K	Project Manager	Software Testing	>20 years	Public
L	Software Engineer	Software Testing	>10 years	Public

IV. ANALYSIS AND FINDINGS

A. The Analysis

The analysis was carried out in five steps which adapted from Creswell [47]. The steps are:

1) Step 1: Organize and prepare the data for analysis. This involves transcribing interviews, optically scanning material, typing up field notes, cataloguing all of the visual material, and sorting and arranging the data into different types depending on the sources of information.

2) Step 2: Read the whole text or scripts. This step provides a general sense of the information and an opportunity to reflect on its overall and clear meaning of the text.

3) Step 3: Coding. This is the process of organising the data by connecting chunks (or text or image segments) and writing a correct word representing a specific category [48]. It involves taking text data or pictures gathered during data collection, segmenting sentences (or paragraphs) or images into categories, and labelling those categories with a term, often a term based in the actual language of the participant.

4) Step 4: Interpreting the data. Use the coding process to generate a description of the setting or themes for analysis. Advance how the description and themes will be represented in the qualitative narrative. The most popular approach is to use a narrative passage to convey the findings of the analysis. This might be a discussion that mentions a chronology of events, the detailed discussion of several themes (complete with subthemes, specific illustrations, multiple perspectives from individuals, and quotations) or a discussion with interconnecting themes.

5) Step 5: Validation of Findings. The data analysis is finalised by validation process to ensure the findings are correct and accurate. The process is carried out with the experts to validate and verify the findings.

B. Findings

Twelve interview scripts have gone through verification analysis and texts were read repeatedly to understand the implicit intent. From the analysis, 112 codes have been identified and created. The codes were sorted based on similar meaning or categorisations. There are 24 codes obtained through the analysis process. After the theme categorisation process, codes are grouped into three which are issues in software measurement, elements for software metric selection, and criteria for software metric selection.

The content analysis discovered several codes associated with group and categorisation. In group one which is issues in software metric, the analysis identifies five codes and for group two which is about elements for software metric selection, six codes are grouped in this category. While in the third group which is related to metric selection criteria, the analysis reveals 13 codes from the coding analysis and theme representing process. Table III shows the findings.

1) Issues in software measurement: Based on the findings of this study, it revealed that there are still issues and challenges in implementing software measurement. The view

and opinion are similar in government and private sector and they revealed lack of commitment, no guidelines or systematic procedure, limited expert resources, and limited metric resources gave impact and consequence toward software measurement and assessment program. The frequency analysis shows that no guideline or systematic procedure achieve 16 times more often given by the informants. This means that no guidelines are the highest and important issue given by informants of this study. While 15 times were given and highlighted by informants on the issues of lack of commitment and experts in metrics selection. Furthermore, the informants gave 13 times highlighted on lack of software metric resource and 10 times occurrence in the scripts for non-compliance to goal and objective. The detail frequency analysis is shown in Table IV.

2) The elements for software metric selection: In the effort of preparing the structured approach in software metric selection, informant's views and opinion were asked regarding the necessary elements during the selection process. The identified elements will be used as the main elements or components needed in the structured software metric selection model. Findings for Part B of the interview instrument are shown in Table V. It shows that evaluation criteria is the most popular element identified by the interview informants where it appears 14 times more frequent in the interview scripts. While the second highest in term of times frequent are the target and data collecting technique with 12 times. Next, is standard reference with 10 times highlighted by informants and follows by synthesis technique and evaluation process with eight times highlighted and appeared in the scripts. The detail frequency analysis is illustrated in Table V.

C. Criteria for Software Metric Selection

Informants of this survey expressed their views and opinions on essential criteria for software metric selection process. Based on frequency shown in Table VI, measurement scale received high frequency which is 16 times given by informants. This shows that informants highlighted 16 times saying that measurement scale is the important criteria during evaluation of metric selection. Second highest frequency is measurement independence (14 times) and third highest frequency is cost and programming language independence (13 times). This follows by automation (12 times) and accuracy and simplicity with 11 times. Meanwhile, environment, feedback and applicability appear 10 times occurrence in the informant's scripts. The last three criteria which are green ability, type of users and comparable receive nine times occurrence in the informant scripts, respectively.

TABLE III. CONTENT ANALYSIS ACCORDING TO GROUP AND CATEGORISATION

Group 1	Issues in software measurement	1. Lack of commitment 2. Lack of expert 3. No metric resource 4. No guideline 5. Non-compliance to organisation's objective
Group 2	Elements for software metric selection	1. Target 2. Selection criteria 3. Reference standard 4. Data collection technique 5. Synthesis technique 6. Evaluation process
Group 3	Metrics Selection Criteria	1. Measurement scale 2. Measurement independence 3. Automation 4. Cost 5. Accuracy 6. Simplicity 7. Environment 8. Type of users 9. Programming Language Independence 10. Feedback 11. Comparable 12. Applicability 13. Green ability

TABLE IV. FREQUENCY OF ISSUES IN THE INFORMANT SCRIPTS

Issues	**Informant**												**Total**
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	
No guideline	1	1	1	1	2	1	1	1	1	2	2	2	16
Lack of commitment	1	1	1	1	1	1	1	1	1	2	2	2	15
Lack of Expert Resources	1	1	1	1	1	2	0	1	1	2	2	2	15
Lack of metric resources	1	1	1	1	1	1	0	1	1	2	2	1	13
Non-compliance to goal & objective	0	0	0	1	1	1	0	2	1	2	1	1	10

V. Results and Discussion

Findings from this study shows that failure in measurement program still exists and is relevant in today's software quality challenge. The failure of this program causes by lack in commitment among software developers, practitioners and stakeholder, lack of guideline, limited number of expertise in this area, lack of metric resources and non-compliance to organisational objective. The first part of the interview reveals that we still need a new model for measurement program, a systematic guideline for metric selection and a repository for available software metric which can be accessed by many people in this area and compliance with the organisational goal and objectives.

While the second part of the interview instruments and analysis revealed that the essential elements for selection metric are: target, selection criteria, reference standard, data collection technique, synthesis technique, and evaluation process as demonstrated in Table V. Even though some of these items are not being practiced currently by the informants in the industry but they agree that these elements are needed to support the selection and evaluation process. Lack of standard and structured approach or mechanism will avert the successful of measurement program in organisation.

Furthermore, this expert interview study discovers and verifies that selection criteria supports organisation in metric selection process based on certain criteria and unique characteristic of metric. The identified criteria for metric selection process can be used in systematic software evaluation. Organisations and stakeholders may understand more on the importance of the selected metrics suitable and appropriate for their requirements based on organisation's goal and objectives. The verified criteria are shown in Table VI.

Based on these findings and also supported by literature study, the definition and detail description on each of the criteria are presented in Table VII.

TABLE V. Frequency of Elements in the Informant Scripts

Elements in Metric Selection	**Informant**												**Total**
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	
Evaluation Criteria	1	1	1	1	2	2	1	1	1	1	1	1	14
Target	1	1	1	1	1	1	1	1	1	1	1	1	12
Data Collection Technique	1	1	1	1	1	1	1	1	1	1	1	1	12
Reference Standard	1	1	1	2	1	2	1	0	0	0	0	1	10
Synthesis Technique	1	1	1	1	1	2	1	0	0	0	0	0	8
Evaluation Process	1	1	1	1	1	1	1	0	0	0	0	1	8

TABLE VI. Frequency of Criteria in the Informant Scripts

Criteria for metric selection	**Informant**												**Total**
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	
Measurement scale	2	1	1	2	2	2	1	1	1	1	1	1	16
Measurement independence	1	1	1	1	1	3	1	1	1	1	1	1	14
Cost	2	1	1	1	1	1	1	1	1	1	1	1	13
Programming language independence	1	2	1	1	2	2	1	1	1	0	0	1	13
Automation	1	1	1	0	1	2	1	1	1	1	1	1	12
Accuracy	1	1	1	0	1	3	1	1	1	0	0	1	11
Simplicity	1	1	1	1	1	2	1	1	1	0	0	1	11
Applicability	1	1	1	0	2	1	1	1	1	0	0	1	10
Environment	1	1	1	1	1	1	1	1	1	0	0	1	10
Feedback	1	1	1	0	2	1	1	1	1	0	0	1	10
Type of users	1	1	1	0	1	1	1	1	1	0	0	1	9
Comparable	1	1	1	0	1	1	1	1	1	0	0	1	9
Green ability	1	1	1	0	2	1	1	1	0	0	0	1	9

TABLE VII. THE DESCRIPTION OF METRIC CRITERIA

	Criteria	**Description**
1	Measurement scale	Scale that being used for categorising and measuring certain metric. Four main scales normally used are: nominal, ordinal, interval and ratio.
2	Measurement independence	The ability to obtain same result for different users. The consistency and stability of the metric.
3	Automation	The effort of measuring using support tool.
4	Cost	Referring to the cost implication in metric. Simple metric will reduce cost and complex metric will increase cost.
5	Accuracy	The accuracy of the measure.
6	Simplicity	Metric should be easy to be used and understood by the users.
7	Environment	Is the metric require control environment such as in lab? Or in the uncontrolled environment such as at home?
8	Type of users	Type of users involve in the metric evaluation. If larger target group or users, more cost will be needed.
9	Programming language independence	Metric should be independent from any programming language or any specific programming syntax.
10	Feedback	Metric should provide further information or prediction on product quality.
11	Comparable	Metric should be able to compute and compare to understand the real situation.
12	Applicability	Metrics should be applied and appropriate for certain phase in software life cycle
13	Green ability	Metric should support green with minimum or less effect on environment.

VI. CONCLUSION

This paper has presented the findings from qualitative expert interview on three main issues which are issues in software measurement, elements for software metric selection process, and metrics selection criteria. The aims are to identify the current practices in the industry, issues and challenges in metric selection and evaluation, metric selection and evaluation process in industry specifically in public sector. The empirical study was conducted in Malaysia that involved 12 experts and practitioners in software evaluation, testing and measurement. The study has discovered five main issues related to software measurement face by the industry as discussed in this paper. Furthermore, it revealed 13 essential criteria and six main elements for software metric selection process. This finding will be applied and used in construction of the Structured Software Metric Selection Model as our future work.

VII. FUTURE WORK

For decades, measurement and metrics is important activities due to the growing interests of software companies in the improvement of the productivity and quality of delivered products. Future research is needed to explore the potentials of measurement program to have a software metric selection model which integrate software metric selection elements and criteria, systematic software metric selection guideline and a comprehensive repository for available software metrics which compliance with the organisational goal and objectives. Last, software metrics selection process needs to adapt the model, guideline and repository in order to ensure software product quality.

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Systematic Review of Existing IoT Architectures Security and Privacy Issues and Concerns

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***Abstract*—Internet of things (IoT) has become one of the most prominent technologies that the world has been witnessing nowadays. It provides great solutions to humanity in many significant fields of life. IoT refers to a collection of sensors or object in the universe with the capability of communicating with each other through the internet without human intervention. Currently, there is no standard IoT architecture. As it is in its infancy, IoT is surrounded by numerous security and privacy concerns. Thus, to avoid such concerns that may hinder its deployment, an IoT architecture has to be carefully designed to incorporate security and privacy solutions. In this paper, a systematic literature review was conducted to trace the evolvement of IoT architectures from its initial development in 2008 until 2018. The Comparison among these architectures is based on terms of the architectural stack, covered issues, the technology used and considerations of security and privacy aspects. The findings of the review show that the initial IoT architectures did not provide a comprehensive meaning for IoT that describe its nature, whereas the recent IoT architectures convey a comprehensive meaning of IoT, starting from data collection, followed by data transmission and processing, and ending with data dissemination. Moreover, the findings reveal that IoT architecture has evolved gradually across the years, through improving architecture stack with new solutions to mitigate IoT challenges such as scalability, interoperability, extensibility, management, etc. with lack consideration of security solutions. The findings disclose that none of the discussed IoT architectures considers privacy concerns, which indeed considered as a critical factor of IoT sustainability and success. Therefore, there is an inevitable need to consider security and privacy solutions when designing IoT architecture.**

Keywords*—Internet of things; IoT architecture stack; IoT layers; IoT privacy concerns; IoT security

I. Introduction

Recently, new technology has emerged with a number of solutions to facilitate the way of interacting with any object in the world. The promising technology of the Internet of Things (IoT) offers many attractive and useful solutions to help improve communication with everything in the surrounding world. IoT assists people to interact with objects as a new paradigm of communication. This technology promises that the things around us will become smarter and more intelligent. Therefore, the technology of IoT is a recent communication paradigm that is highly integrated into our daily life, providing various applications that can change our lifestyle by making it easier, safer, and smarter [1], [2]. Although many definitions for IoT have been derived by scholars, so far, there is no standard definition for IoT [3]–[5]. The essence of IoT is that all things surrounding us can connect to the Internet and exchange data anywhere and at any time [6], [7].

The Internet of Things (IoT) will play an essential role in many aspects of our daily life. This technology was designed to tackle problems that arise because people have limited time, attention and accuracy when collecting data from things in the real world. The primary aim of IoT is to simplify our daily lives and mutate our way of accomplishing or fulfilling duties [8]–[10]. IoT can be employed to improve many important fields (e.g. healthcare, automobiles, entertainments, industrial appliances, sports, homes, transportations, smart grids, and intelligence systems) [7], [11], [12]. Furthermore, it can be used in the food industry, restaurants, logistics, tourism, travel, and library services [13], [14]. In addition, it can be useful for improving the governmental services provided for citizens, such as e-participation, e-aging, disabled people, etc. [10]. Technology reports on IoT show a dramatic change in the way we work and live due to the impact of IoT on industry and society [2]. The potential economic impact of IoT and its supporting technologies is estimated to reach a price ranging from $3.9 trillion to $11.1 trillion a year by 2025 [15]. It provides great benefits, including home monitoring, health monitoring, agriculture monitoring, energy monitoring and control, environmental monitoring, smart education, smart security, etc. [16]. The future will witness many smart applications in different fields. IoT will offer potential value to the consumers. For example, in smart automobiles, IoT can be used to detect the traffic jam on the road and notify the driver to take a decision to avoid any inconvenience that can occur due to traffic jam [17]. The most beneficial value gained from IoT is when it is used in critical fields, such as in predicting natural disasters. In this case, the sensors and autonomous simulations can predict the occurrence of earth-slides and other disasters. Furthermore, according to such detection, appropriate action can be taken in advance. Another important field that IoT can offer significant value to is an industry. For example, IoT can assist in the management of a fleet of cars for an organization, monitor their performance and detect which one needs maintenance. A significant application can be seen in monitoring water scarcity, where an IoT device can detect scarcity in different locations and can alert users if an upstream incident occurs as well, such as an unintentional release of sewage into the stream, which has dangerous implications. In addition, an appreciable advantage of IoT can be noticed when monitoring patients and saving their lives. Agriculture and other important fields can utilize IoT to perform accurate tasks

[18]. Moreover, IoT provides a benefit for waste management, which is an issue in modern cities. In these regards, an intelligent waste container can be used to detect or sense the level of load and, thus, allow for optimizing the route of the collector trucks, which can help in reducing the cost of waste collection and improving the quality of recycling [19]. Furthermore, smart cities utilize IoT to improve their infrastructure, keep people safe, engage more residents, improve public transportation, etc. Cities become smarter by means of IoT when all critical systems, including transportation systems, healthcare systems, and weather monitoring system, are connected [1]. When cities become smart, numerous benefits can be gained in the management and optimization of services, such as transport, parking, lighting, surveillance, maintenance of the public area, garbage collection, etc. [20].

Although IoT offers a range of significant and substantial solutions to the world, many challenges can stand a hindrance toward the success of IoT. These challenges, as mentioned in the surveys of [18], [21]–[24], are related to the scalability issues, data volumes, data interpretation, interoperability, fault tolerance, power supply, wireless communication, privacy, and security, etc. However, to date, security and privacy are considered the topmost challenges that need to be addressed, as they are considered a complementary requirement for IoT development [25], [26]. In 2013, the first IoT botnet was discovered, and according to a researcher at the Proof point, more than 25% of the botnet was created on IoT devices, including smart TVs, baby monitor, cameras, home appliances, etc. [27]. Security concerns may occur at any level of IoT, such as at the front-end sensors and devices, network, and at the back-end of IT systems [28]. Also, the privacy of users may be exposed as a result of serious breaches of users' sensitive information, which may occur in devices, storage, during communication and at processing [29]. Therefore, users' privacy has to be preserved using techniques, in order to protect the device privacy, as in [30], [31], during communication through using [32], at storage using [33], and at processing using [34]. To address these two challenges, the environment of IoT must be well-studied and analyzed from different aspects, like IoT architectures, consumers' needs, stakeholder's requirements, technologies used, and other aspects. In this paper, a systematic review was conducted to study the existing IoT architectures in terms of layers' classification and the considerations of security and privacy in IoT architectures.

The remaining paper is organized as follows: Section 2 presents the research methodology that is used to achieve the objectives of this research. Section 3 introduces background details related to IoT history, privacy and security concerns in IoT. Section 4 surveys the existing IoT architectures. Section 5 provides the discussion of IoT architectures in terms of the consideration of privacy and security, covered the issue in architecture with techniques used, architectural stack (the number of architectural layers). Section 6 concludes the conducted review.

II. Research Methodology

The paper provides a systematic literature review to study the existing IoT architectures. Precisely, the systematic literature review provides a comparison between sixteen of the existing IoT architectures that were developed between 2008 and 2018 [5], [18], [43], [35]–[42]. To accomplish the systematic literature review, the methodology of this study is divided into steps, as depicted in Fig. 1.

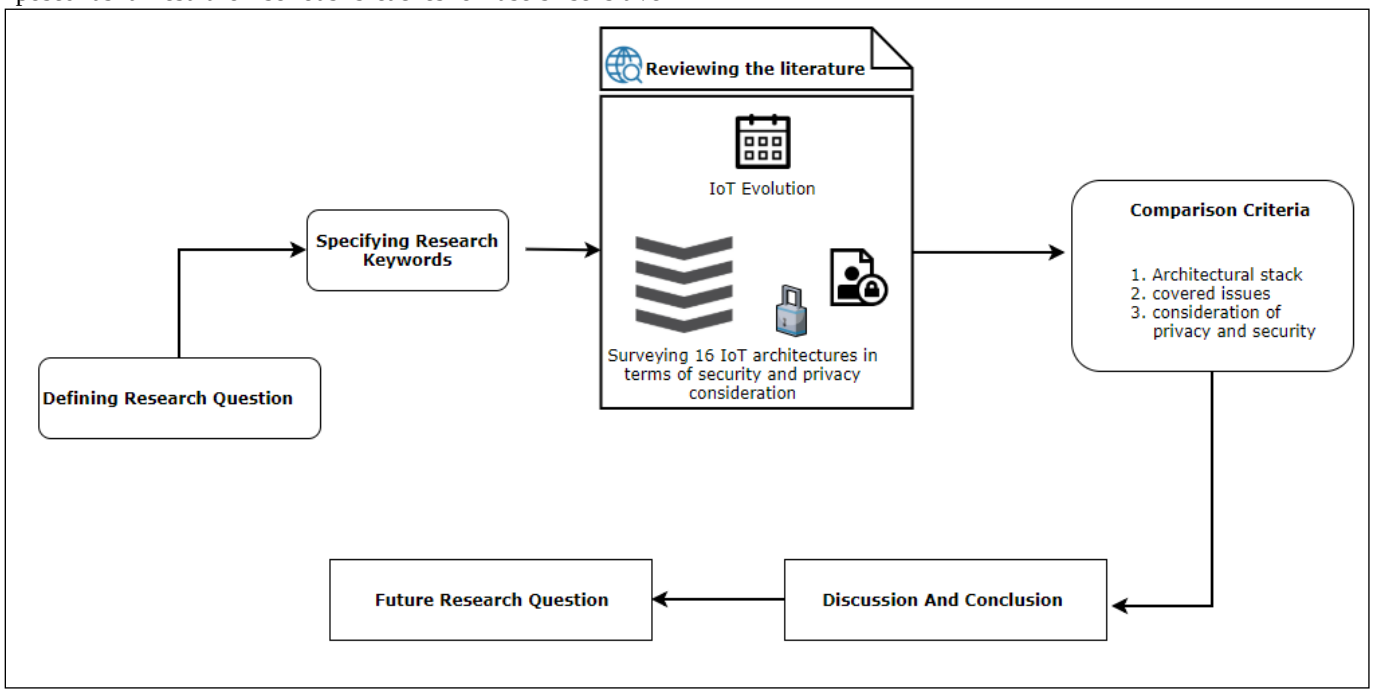

Fig. 1. Methodology of the Systematic Review Study on the Existing IoT Architectures.

As shown in Fig. 1, the methodology of this study is divided into the following steps:

- Defining the research question.
- Specifying research keywords.
- Reviewing the literature.
- Specifying comparison criteria.
- Discussions and findings.

A. Research Questions

The aim of this research is to study and compare the existing IoT architectures in terms of the architectural stack, covered issues, and consideration of security and privacy aspects. The systematic review aims to address the following research questions:

1) Is there a standard IoT architecture? To answer this question, the researcher studied all the existing sixteen IoT architectures that were proposed during the period 2008 and 2018. This research question was divided into the following sub-questions.

- What are the IoT architecture layers or stack?
- Do all layers provide the same meaning for describing IoT?
- Do the existing IoT architectures thoroughly provide a complete meaning to IoT nature?

2) Are security and privacy considered as essential components of the IoT architecture? To answer this question, the focus was on studying the security and privacy in each of the selected IoT architectures. This question was divided into the following sub-questions:

- What are the issues that IoT architectures covered and the used techniques?
- Are security and privacy aspects implemented in IoT architectures?
- What are the open research questions related to the IoT architectures, as well as the security and privacy aspects?

B. Research Keywords

The research keywords were extracted from the research questions. Table 1 presents the research keywords, which were used for searching the resources, used in this paper.

TABLE I. RESEARCH KEYWORDS

No.	keywords
1	"IoT architecture"; "internet of things architecture"
2	"IoT layers"; "internet of things layers"
3	"IoT privacy"; "Internet of things privacy"
4	"IoT security"; "Internet of things security"

The search strings S1 and S2 are formed as a disjunction of the first two lines, and a conjunction of the disjunction of the last three lines of the specified keywords:

S1=: L1 OR L2 AND (L3 OR L4)

S2=: L1 OR L2 AND (L3 AND L4)

In addition, each line represents a disjunction of its selected keywords, e.g. L2 =: {IoT layers OR internet of things layers}.

C. Reviewing the Literature

In this systematic literature review, 148 resources from different online databases were used. Most of the research papers used in this review were found on google scholar, IEEE, Future Generation Computer System, ICCCN, ICICTA, IEEE Xplore, ACM, COMNET, and other databases. The selection of the architectures was based on the year that the architecture was developed in, starting from the first IoT architecture, which was proposed in 2008, and covering all the IoT architectures that were proposed until 2018. Each of the selected IoT architecture was comprehensively studied and classified according to the number of IoT layers as:

1) Three-layer IoT architecture
2) Four-layer IoT architecture
3) Five-layer IoT architecture

D. Specifications of the Comparison Criteria

Use The selected IoT architectures have been studied, and a comparison between these architectures was conducted in terms of the number of IoT layers in each architecture, their architectural stack, and whether the architecture has considered security and privacy aspects.

1) Architecture stack (IoT layers): each architecture consists of layers that are used for describing the complete nature of IoT, starting from data collection and ending with data presentation. This criterion is used because the main components of IoT architectures are the layers that cover a subset of the required IoT functionalities or processes.

2) Covered issues and challenges: This criterion is used to show how the IoT architecture evolves over the years, and to highlight what each architecture address.

3) The technique used: This criterion is used to present the technology used for addressing the IoT challenges to improve IoT architecture.

4) Security: This criterion is very crucial because security in IoT is considered the key driver for IoT success. Thus, security should be considered in IoT architecture.

5) Privacy: This criterion has received most of the attention so far, because it touches IoT users and, thus, leads to the acceptance of IoT among users. The ways on how to preserve users' privacy must be considered in IoT architectures.

III. BACKGROUND AND OVERVIEW

A. History of the Internet of Things

The idea of connecting devices together has been around since the 1980s. Then, the concept changed to the terms of embedded computing and persuasive computing. In the early

80s, the first example of the Internet of Things appeared as a Coca-Cola machine, which was located at Carnegie Melon University. This machine had the ability to count the number of drinks left, and measure whether they are cold enough or not [44]. During the period between 1980 to 1990, many companies in America and Europe focused on manufacturing radio frequency identification (RFID) tags. Essentially, an RFID tag was used to identify an object. In the same period, this technology of object identification (RFID) was deployed for automatic toll payment application [45]. Moreover, the 1990s witnessed the great movement of shifting from machine-to-machine (M2M) to wireless technology [46]. Global Positioning Satellites (GPS) begun to be used in 1993 [47]. This technology was used to determine the location of an object. In 1998, the use of the term Internet of Things was presented by Kevin Ashton [5], [48]. The year 1999 was called the big year of this new term when the British technology pioneer Kevin Ashton (executive director of auto-ID center) coined the new term as the Internet of Things (IoT), which started gaining more popularity in academia and industry [44], [49], [50]. In 2000, the first Internet-connected refrigerator was announced by LG [44]. In the years of 2003 and 2004, the IoT-supporting technology of RFID was extensively used by Walmart and the US Department of Defense [44]. Moreover, in the same years, the IoT term had appeared in well-known publications like the Guardian, Scientific American and the Boston Globe. In 2005, ITU-T published the first article on IoT [51]. IoT was recognized by the EU in the period between 2006-2008, and accordingly, the first European IoT conference was held [52]. The statistics shown by Cisco Internet Business Solutions Group (IBSG) confirm that IoT was born between 2008 and 2009, due to the increase in the number of things or objects that were connected to the internet, which exceeded the number of people. In 2010, China considered IoT a key industry and made plans to focus its investment on it. Furthermore, IPv6 was launched in 2011 with the capability of providing 2^{128} addresses, which is sufficient to address every atom on earth [53]. The IPv6 protocol can be used in IoT. In 2012, the technology of mobile computing became popular and used in IoT development. As the number of connected IoT devices increased, many challenges emerged and many solutions were introduced such as IoT platforms. Most of Known IoT platforms were launched in 2013 [54]. Many of proprietary and open source platforms were introduced to accelerate IoT development. In the same year, an IoT group was created by Intel company, and later, in 2015, an operating system for IoT called Brillo was developed by Google [44]. Subsequently, a drastic change was noticed in the way people perceive the promising technology due to the major evolution in technologies, such as embedded systems. As a result, billions of IoT devices were connected to the Internet. In this regard; Statista (the statistics portal), which presents statistics and studies from more than 22,500 sources, expected that the number of connected IoT devices to reach 30.73 billion devices by 2020, and 75.44 billion by 2025 [55], [56]. IDC estimated that global IoT spending will reach $1.29 trillion by 2020 [57], [58]. In [59] authors predicts that the number of connected cameras to the internet will reach 100 billion in 20130 (Internet of video things). Fig. 2 illustrates the history and evolution of IoT.

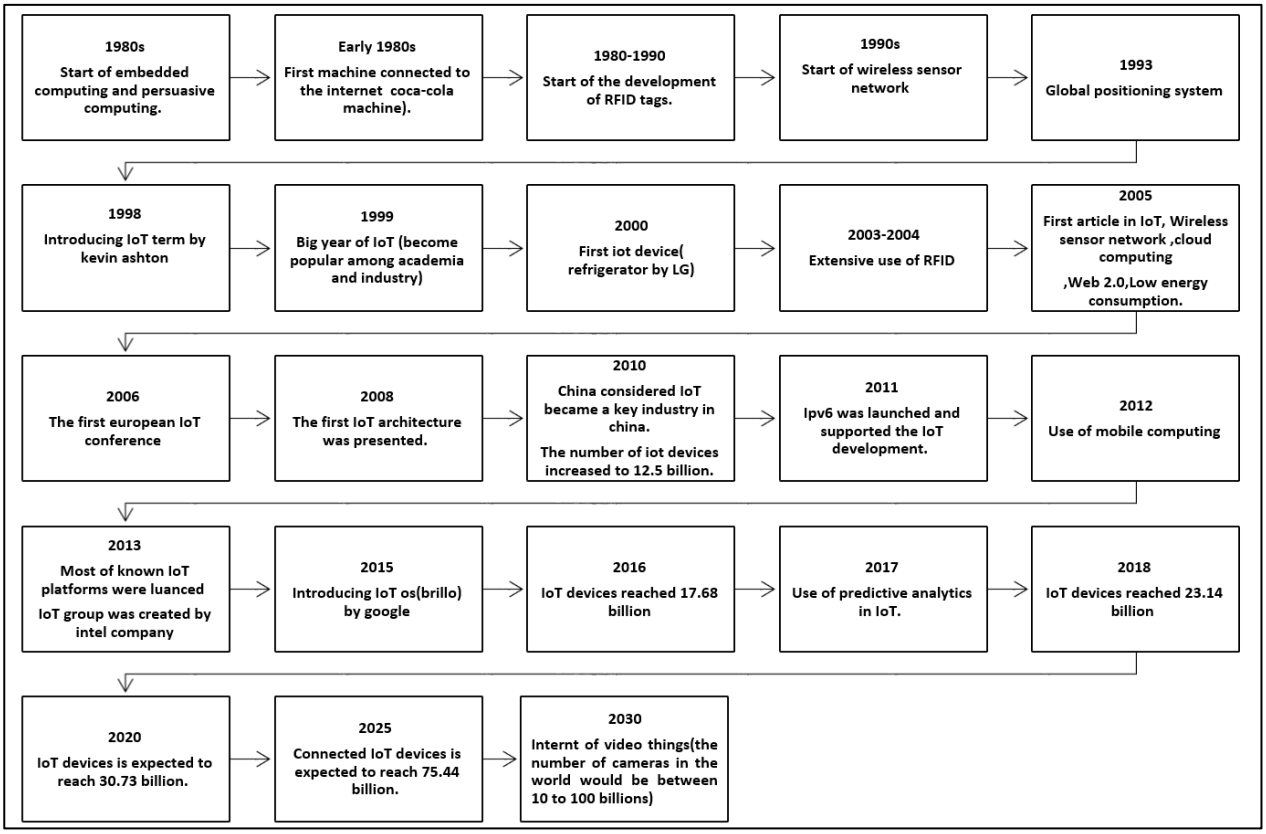

Fig. 2. Summary of IoT History and Evolution.

As presented in Fig. 2. IoT has been gradually evolving due to the development of many technologies, such as RFID, wireless sensor network, global positioning system, cloud computing, web 2.0, low energy communication, IPv6, mobile computing, analytics systems, and other new technologies. The analysis of IoT history also shows that the number of IoT devices has increased in recent years, and is expected to rise sharply in the coming years, which indicates that IoT will intervene in every corner of our life.

B. Internet of Things Definition

At present, there is no standard definition accepted for IoT, as it is still in its formation process [5], [50]. A lot of communities and organizations defined IoT according to their perspectives. RFID community defined IoT as things-oriented in which tags are a thing [60]. They defined IoT as; "the worldwide network of interconnected objects uniquely addressable based on standard communication protocols" [6], [61]. Another definition was formed by the European Research Cluster of IoT (IERC), in which they defined IoT as; "The Internet of Things allows people and things to be connected anytime, anyplace, with anything and anyone, ideally using any path/network, and any service" [6], [62]. The International Telecommunication Union (ITU) defined IoT as; "From anytime, anyplace connectivity for anyone, we will now have connectivity for anything" [6], [63].

Through the concept of the Internet of Things, things in the world can integrate and communicate with each other, in order to serve humans in their daily lives. Generally, the Internet of Things (IoT) refers to collections of various sensors, objects, and smart nodes, which have the capability to communicate with each other, without any intervention from people [11]. More specifically, it involves connecting any device that has the feature of switching off or on through the internet. To be more specific, it includes everything, such as cell phones, headphones, washing machines, lamps, wearable devices, and an electronic device that anyone can think of [17]. IoT provides devices with the capability to sense (think, see, and hear) from the environment and make a decision [64], [65]. A device can be considered as a node in the IoT, therefore, each node has the ability to transfer lightweight data, access and authorize cloud-based resources for the purpose of collecting, extracting data and making decisions through the analysis of the collected data [11].

C. Nature of the Internet of Things

The main purpose of IoT is to facilitate the process of exchanging information among things and retrieving useful knowledge from the exchanged information [5]. The great value of IoT is to improve the services of collecting, analyzing, and extracting knowledge for different purposes. To perform these services, IoT should possess three main characteristics, which are; comprehensive perception, reliable transmission, and intelligent processing [66], [67]. Comprehensive perception involves diverse devices, such as sensors and RFID, to obtain information from any object, anywhere and at any time. The reliable transmission includes a variety of wired and wireless networks that are used for data transmission. Intelligent processing is about having technologies like cloud computing, which is used for storing and processing the obtained data by sensors [67]. In order to make this new technology a reality, many related technologies support the evolution of IoT, such as wireless sensor networks, cloud computing, communication networks, mobile technologies, identification technologies, big data, security and privacy technologies, distributed computing, and fog computing [1]. Mainly, the IoT environment relays on the internet, mobile communication networks and wireless sensor networks [68]. IoT can benefit from the unlimited capabilities of cloud computing, which are mainly used for the storage and processing of data [69]. Cloud computing can also enable data collection, accelerate the setup and integration of new things, and reduce the cost of deployment [70]. Big data technology can be utilized in IoT where the collected data from sensors can be analyzed to give a better understanding of the physical world[71]. Since IoT is susceptible to attacks like Denial of Service attack(DoS), Distributed Denial of Service attack(DDOS), compromised nodes, and malicious code hacking attacks, specific security technologies, such as homomorphic and searchable encryption, can be used to make IoT secured [1], [72]. IoT is related to a distributed computing technology where the Internet can extend into the real world to connect everyday objects [73]. In addition, IoT is related to fog computing technology where computing, storage, control, and networking power can be placed anywhere, for example in data centers, cloud, edge devices, sensors, and gateways [74], [75]. Furthermore, Nanotechnology is also related to IoT, where Nano-devices can be integrated with the communication network and with the Internet to form the Internet of Nano things [76]. Fig. 3 depicts IoT and related technologies.

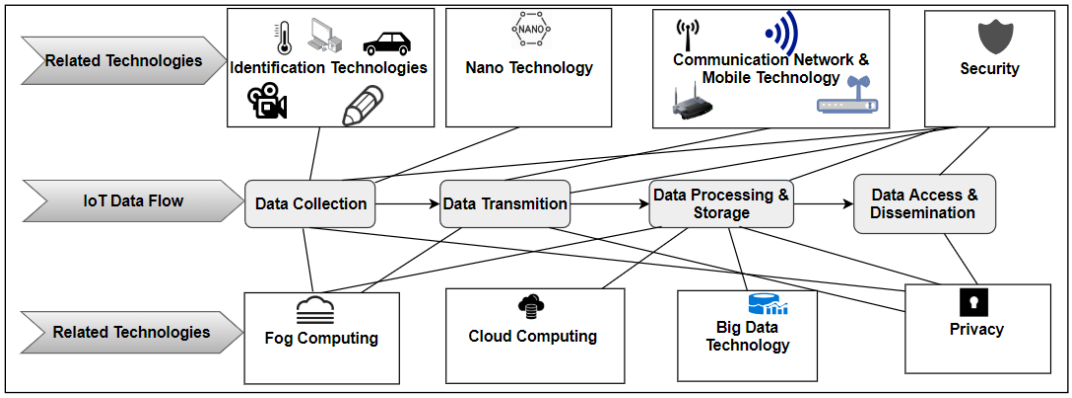

Fig. 3. IoT and Related Technologies.

As mentioned earlier, IoT provides some useful benefits, such as home monitoring, health monitoring, agriculture monitoring, energy monitoring and control, environmental monitoring, smart education, smart security, etc. [77], [78]. Regardless of the great benefits offered by IoT, many challenges and concerns hinder its development and success [24], [79]. Some surveys, such as the surveys of [18], [21]–[24], [80], were conducted to discuss the challenges of IoT. Nevertheless, to date, security and privacy concerns are the major challenges [25], [26], [81] that scholars are paying more attention to, in order to discuss and address the IoT challenges.

D. Security and Privacy in the Internet of Things

Security and privacy requirements for IoT are essential for mitigating failures and ensuring the acceptance of IoT by customers [82]. Some researchers consider privacy as part of security issues [11], [83], [84]. Indeed, there is a noticeable difference between the terms of privacy and security [85]. Security deals with securing the privacy of data, data through communication, data at storage, data at processing, and securing the access of data [11], [86]. Many security issues are threatening IoT, including vulnerabilities and attacks. For example, the first IoT worm detected in 2013 was called Linux. Darlloz, with the capability of attacking devices like home routers, CCTV, cameras, and other small Internet-enabled devices [87]. During the period from December 23rd, 2013 to January 6th, 2014, another incident attack was detected in smart devices like refrigerators and televisions. These smart devices were hacked to send more than 750,000 spam and phishing emails to individuals [43]. In 2016, the distributed denial-of-service attack took place by exploiting the unaltered default password across a large number of IoT devices [88], [89]. Therefore, the security notion aims to avoid threats that compromise IoT systems and affect the confidentiality, authority, authenticity, integrity, and availability of IoT systems [90]. Various security mechanisms exist to defend various security issues in all IoT layers, as discussed in [1], [43]. Thus, security can be defined as a structured framework composed of policies, procedures, techniques, and measures required to protect the assets of individuals and the systems against threats that may occur deliberately or unintentionally. In other words, security can be defined as a concept that attempts to protect data and devices from external attacks, spyware, and subversion [83].

Whereas security is more concerned about securing data, privacy is more related to people and their data, especially data with a high degree of sensitivity [83]. It is believed that every person should have the right to control his/her private data[62]. The term of information privacy or data privacy was known since the 1960s, due to the increase of electronic data processing [91]. Privacy was defined as "the right to be let alone", by Warren and Brandeis in 1890, in his article of 'The Right to privacy' [92]. Then, privacy was defined by Westin as "the claim of individuals, groups, or institutions to determine for themselves when, how, and to what extent information about them is communicated to others", in his book "Privacy and Freedom" [93]. From the previously mentioned definitions, privacy can be summarized as the release of information in a controlled way. It involves the concealment of personal information and the ability to control personal data [94]. To be more specific, privacy means that the person has the right to determine the level of his/her interaction with the environment, or the amount of data that can be viewed for the public [28], [62], [83]. Weak security measures in IoT devices lead to privacy breaches and safety threats in the real world [95]. There are large overlaps and intersections between security and privacy concepts, but there is a notable difference between the terms, as Fig. 4, illustrates [83]. Generally, the manufacturers of IoT concentrate and care about hardware security more than they care about users' privacy [83].

IoT devices can leak sensitive information, as shown by recent studies [96]. For example, the data collected by smart switches, smart thermostats, and smart power meters can leak information, including information about whether a home is being occupied [97], [98]. Furthermore, IoT devices (e.g. rooftop solar panels) can reveal home location [99], [100]. In solar energy analytics, energy data can leak location information, which may cause location-based privacy attacks [96]. In critical fields (military, as an example), the privacy threat is very dangerous, because IoT devices can leak sensitive information that the enemy can exploit. For instance, Strava fitness app posts a map of its users' activity on the internet. Security researchers showed that this public activity map imposes a severe threat to the U.S national security by indirectly revealing the locations and behaviors or attitudes of the U.S military bases and personnel in Syria and Iraq [96], [101]. In healthcare, many IoT applications were developed to serve this sector, including apps used for sensing glucose level, monitoring blood pressure, monitoring ECG, etc.[102]. These applications are exposed to attacks and vulnerabilities [103]. In IoT devices, such as an insulin pump that was manufactured by Medtronic company, the system does not provide adequate security to the command sent to the pump by patients. This lack of security leads to serious privacy issues. Some of these issues are revealing patient's information by third parties, intercepting commands and replacing them, and threatening patients' lives by delivering a fatal insulin dose to the patient as well [104]. In smart cars, vulnerabilities have been found, and they can threaten people's lives. Tesla Model S was hacked by security researchers at a keen security lab, through disrupting all the car features, such as brakes, the door lock, disclosing locations and controlling computer screen from a distance of 12 miles [104]. For this reason, taking IoT privacy into consideration leads to gaining wider acceptance of IoT by customers and, thus, leads to IoT success [82]. In order to mitigate security and privacy issues in IoT, IoT architectures have to be investigated and studied. The following section surveys the existing IoT architectures in terms of considering privacy and security aspects, and the number of IoT architectural layers.

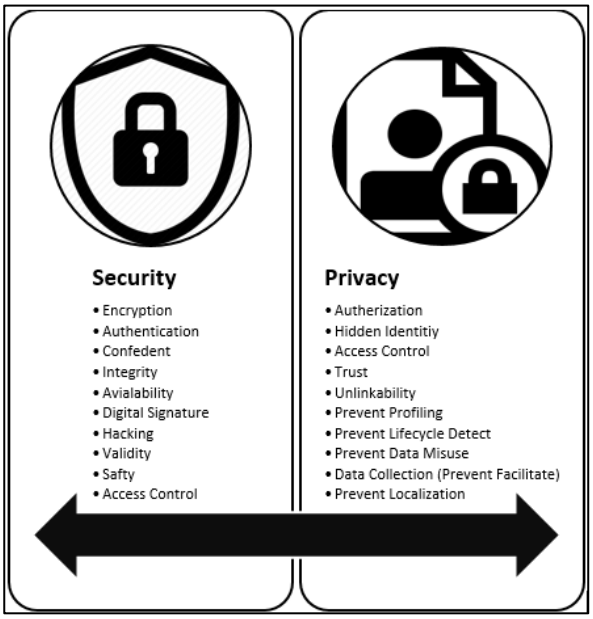

Fig. 4. Difference between Security and Privacy.

IV. Existing Internet of Things Architectures

Many architectures have been proposed for IoT technology. An architecture helps to understand the nature of IoT and study all the issues that may threaten the promising technology. This section discusses the existing IoT architectures until 2018.

A. IoT Architecture in 2008

In 2008, Pereira [41,123] proposed a five-layer architecture for IoT, which is shown in Fig. 5.

It consists of five layers; named as the edge layer, the access gateway layer, the internet layer, the middleware layer, and the application layer. The edge layer involves all embedded systems, like RFID (Radio Frequency Identification), or sensors that are used for sensing the environment around us. The access gateway layer acts as a cross-platform communication that deals with message routing, publishing and subscribing to the layer above (middleware layer) through the internet layer. Middleware layer acts as the interface between the edge layer and the application layer, and it is responsible for managing information and devices. The topmost layer, the application layer, offers different services from the collected data in the edge layer to various consumers. These applications cover various industries including, but not limited to, food & drug, healthcare, retail, logistics, and public safety.

B. IoT Architecture in 2010

At this stage of IoT development, each application system worked alone, in which an object only communicates with another object in the same application system. As a result, the interoperability issues were common due to the lack of global standards. To solve such issues, Tan in [41] proposed a new layer called the coordination layer.

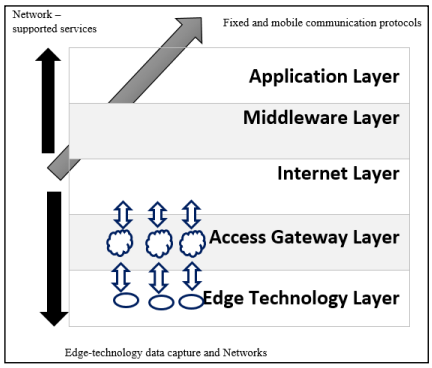

Fig. 5. Five-Layer IoT Architecture [35], [105].

The new layer performs the tasks of restructuring the packages from different application systems and reassembling them in order to form a unified structure that can be recognized and processed by the application system. Due to the nature of IoT, many objects communicate with each other and can generate massive data that leads to an exponential increase in the traffic and storage, which subsequently, creates a number of issues to be solved. To deal with traffic and storage issues, Lu et al. proposed the backbone network layer [35].

In the same year, a three-layer architecture of IoT was proposed by Miao et al. It consisted of three layers see Fig. 7, a perception layer at the bottom, an application layer at the top, and a network layer positioned between the two layers. The perception layer contains all the devices that are used for identifying objects and gathering information (e.g. RFID, 2-D barcode, etc.). Furthermore, it involves the nanotechnology devices that can be used to sense data from the objects in which microdevices are implanted within. The network layer is considered the core of IoT. It has the responsibility of assigning each object a unique address and transmitting the collected data from the perception layer to the application layer in a secure way, using different protocols, such as Wi-Fi, Bluetooth, and ZigBee. The application layer takes the responsibility of managing all applications implemented or developed in IoT. The previously mentioned architecture was the accepted three-layer structure of the new technology of IoT in 2010. It helps to understand the technical structure of IoT at the initial stage of its development.

<table>
<tr><td colspan="2">Application Layer</td></tr>
<tr><td colspan="2">Middleware Layer</td></tr>
<tr><td colspan="2">Coordination Layer</td></tr>
<tr><td colspan="2">Backbone Network Layer</td></tr>
<tr><td rowspan="2">Existed alone Application system</td><td>Access Layer</td></tr>
<tr><td>Edge Technology Layer</td></tr>
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Fig. 6. Five-Layer IoT Architecture [35].

However, Miao et al. [5] argued that the three-layer architecture did not provide a complete understanding of IoT features and meaning. As a result, the authors proposed a new architecture, which was derived from the analysis of the technical framework of the Internet (the core of IoT), and the logic of the layered structure of the telecommunication management network (supporting the technology of IoT). The derived IoT architecture consisted of five layers as shown in Fig. 6. Starting from the bottom, these layers are the perception layer, the transport layer, the processing layer, the application layer, and the business layer. The perception layer, as in the previous three-layer architecture, is responsible for preparing the information gathered by sensors (e.g. RFID, barcodes, etc.) as digital signals to be transmitted over the network. The transport layer performs the process of transmitting the collected data through wireless or cable network technologies. Things (objects) around us generate massive data that must be managed. Therefore, unlike the previous three-layer architecture, this architecture introduced the processing layer that has the duty of storing, analyzing, and processing the information received from the transport layer. Many advanced technologies are used in this layer, including intelligent processing, cloud computing, ubiquities computing, etc. In the application layer, the processed information is utilized in offering a variety of services. The business layer was introduced in this architecture because it can be used to consume the data obtained from the application layer to build business models, graphs and flowcharts, which are useful in evaluating the new technology of IoT. The authors suggested this layer guided by the saying; "the success of the technology relies on the innovation and reasonable of business model". Furthermore, the long-term development and effectiveness of IoT can reach a peak by conducting more research on the business model [5].

C. IoT Architecture in 2011

Until 2011, security was not considered in the IoT architecture. The world today is facing a daunting challenge to deal with many security concerns (for instance, daily virus alerts, increased number of malicious crackers, and the emergence of new cyberterrorism threats). Consequently, security threats have become common, and there is an urgent need to take security requirements into consideration [124]. As any system connected to the internet, IoT devices and applications are exposed to different types of attacks. To resolve security threats in IoT, Li et al. proposed the first IoT architecture that considered security requirements and characteristics of IoT. It was a general architecture of trusted security systems based on IoT. Fig. 9, depicts the proposed architecture.

As Fig. 9, shows the architecture was built of five main components: the trusted safety management system, the security gateway, the unified service platform of IoT, the security infrastructure, and the unified information exchange platform. The trusted user module includes a trusted user authentication system based on IoT. According to this module, identity authentication makes users legitimate. A trusted perception module was designed to address security attacks that may target devices in the perception layer, such as RFID, sensors, camera, laser scanner, etc. These attacks include copying sensed information, a counterfeit of RFIDs labels, distribution of service attack (DoS), unauthorized access of users, and stealing or modifying RFID labels. Security in this layer can be achieved by applying an authentication mechanism, an access control mechanism, an encryption mechanism, and an audit mechanism. Trusted network module basically deals with the accreditation of network users. Moreover, it is responsible for security incident management, risk and strategy management, and the control of many security-related issues. The trusted terminal module deals with securing the platform technology by using encryption techniques and through securing the operating system. Li and his colleagues suggested that this architecture can help decrease the potential risks that may occur due to the access of untrusted users and terminal devices [36].

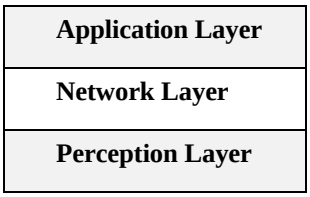

Fig. 7. Three-Layer IoT Architecture [5].

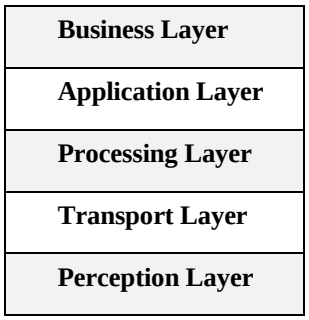

Fig. 8. Five-Layer IoT Architecture [5].

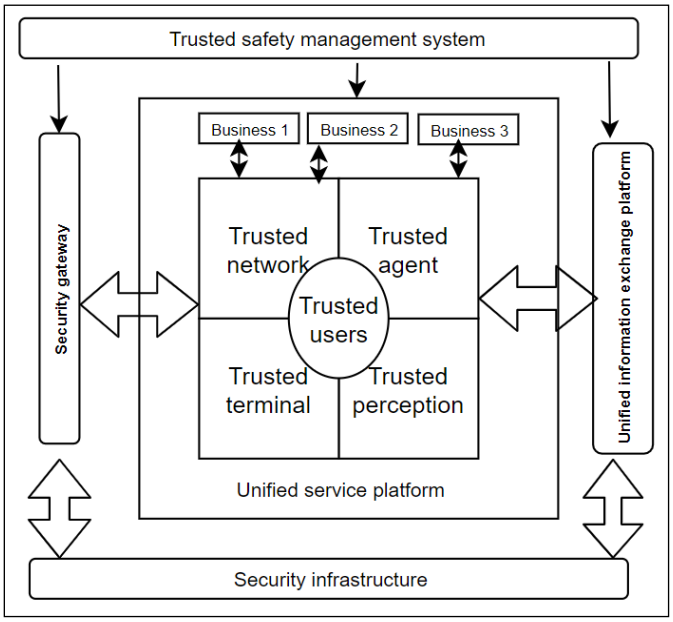

Fig. 9. A General Architecture of Trusted Security Systems based on IoT [36].

In the same year, scalability issues in IoT were considered. In this regard, a 3G-PLC architecture was proposed based on integrating power line communication (PLC) with 3G networks. As shown in Fig. 8, this architecture consists of the three well-known layers of IoT (the perception layer, the network layer, and the application layer), in addition to a newly added layer called the aggregation layer. As discussed earlier, the perception layer includes all of the devices that can sense and collect data from objects. Once data had been collected, the aggregation layer acts as a middleware layer to coordinate information processing, and to translate the data into a standard format. Thus, the formatted data will be transmitted to the network layer. The focus of the 3G-PLC architecture was on the network layer, which combines all types of communication systems, including a 3G mobile network and the technology of Long Term Evolution (LTE). Fig. 10, illustrates 3G-PLC architecture.

As stated before, the 3G-PLC architecture focuses on addressing the scalability issue in IoT, by combining two complex communication networks, which are PLC and 3G. PLC and 3G offer low cost, convenience, and more reliable services. Moreover, PLC can be operated through the existing power line in buildings, which saves significant costs compared to an optical fiber line. The advantage of the 3G node is that it can provide things with useful services such as classification, storage, signal processing, and power saving of the back-end network. 3G-PLC architecture can help in the development of the promising technology of IoT [37].

D. IoT Architecture in 2012

In 2012, a five-layer IoT architecture was proposed by Khan et al. in [27]. The five layers are the perception layer, the network layer, the middleware layer, the application layer, and the business layer, as shown in Fig. 11. The authors discussed that the perception layer can be called a device layer because it includes all the physical things and sensor devices, which mainly deal with identifying things and collecting their specific information. The sensed data from these devices will be transmitted to the network layer. The network layer includes all communication networks, including 3G, UMTS, WIFI, Bluetooth, ZigBee, infrared, etc.

It can be called the transmission layer, and it performs the functionality of transferring or transmitting the collected data from the lower layer to the middleware layer for further processing. In the middleware layer, the collected data received from the network layer will be managed and stored in databases and processed for different purposes. This layer includes techniques or mechanisms used for information processing. Furthermore, ubiquities computation can be performed in this layer for the purpose of making decisions based on the computed data. In the application layer, the processed data from the middleware layer can be utilized by IoT applications and, thus, the application layer will provide global management for similar applications, such as smart health, smart homes, smart buildings, smart or intelligent transportation, etc. In the business layer, the data used in IoT applications can be exploited to build a business model, charts and graphs that may assist in developing or supporting the IoT technology [18].

E. IoT Architecture in 2013

In 2013, an IoT architecture that integrated IoT with cloud computing was proposed by Zhou et al. in [44]. It was called CloudThings architecture, which is an online platform that assists system integrators and solution providers to create a complete infrastructure of things application for developing, deploying, operating, and combining things applications and services. The CloudThings architecture consists of three modules: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service(SaaS), as depicted in Fig. 12.

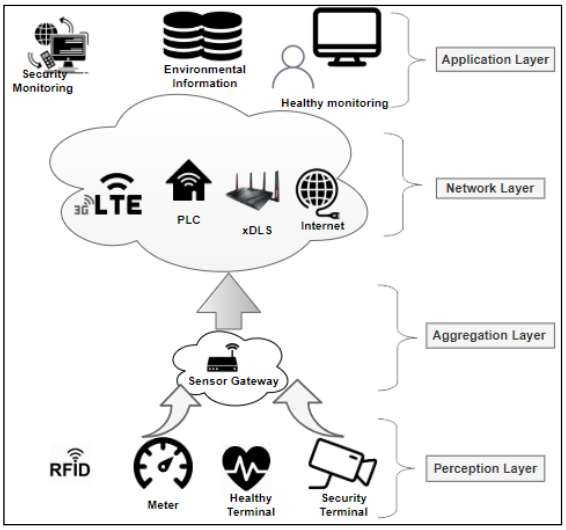

Fig. 10. IoT Architecture based on 3G-PLC[37].

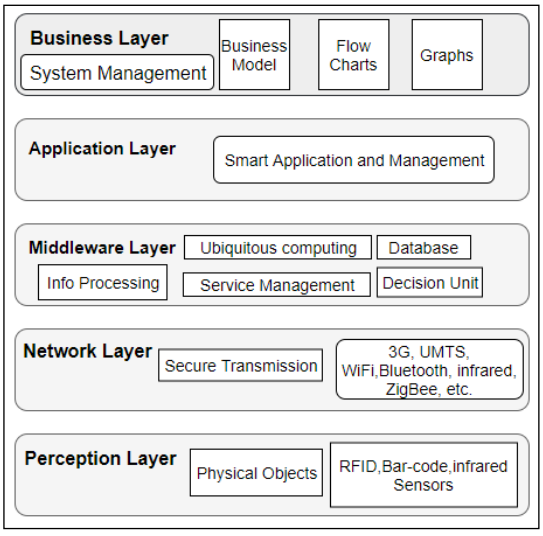

Fig. 11. Five-Layer IoT Architecture [18].

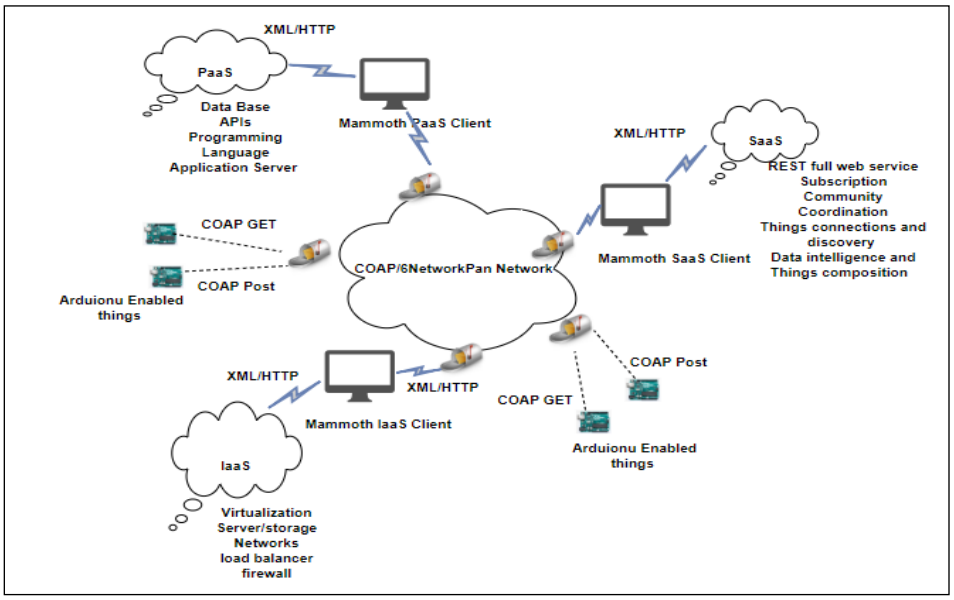

Fig. 12. CloudThings IoT Architecture [38].

CloudThings service platform (IaaS) helps users to run or operate any application on cloud hardware. This module offers users with distinctive management capabilities. It helps direct communication with deceives and offers storage or spaces to collect data on things and helps transmit event of things. The collected mass data can be exposed to an analysis by utilizing cloud computing and storage resources. CloudThings developer suite (PaaS) provides a set of tools for cloud services that can be used for things application development. CloudThings Operating Portal (SaaS) is a set of services provided by the cloud for the purpose of supporting the deployment and handling the special processing services, such as data intelligence and data discovery. The integration of cloud computing in IoT helps to develop things application. Using a cloud-based IoT offers a great advantage compared to traditional or conventional IoT development since the cloud provides services to develop, deploy, run, and manage data online. In other words, the cloud facilitates the development of IoT [38].

F. IoT Architecture in 2015

The nature of IoT imposes the heterogeneity in things that are connected to the Internet. Due to the heterogeneity, interoperability among heterogeneous devices is a challenge. To address such a challenge, Service-Oriented Architecture (SOA) is one solution that may help to ensure interoperability among different IoT devices in many ways. In 2015, SOA of IoT was proposed by Li et al. in [5]., which consists of four main layers, known as the sensing layer, the network layer, the service layer, and the interface layer as illustrated in Fig. 13.

Fig. 13, shows that the layers are displayed horizontally starting from the sensing layer, and ending with the interface layer. Like the previously mentioned IoT architectures, the sensing layer acts as the perception layer, which includes all devices that can sense the status of hardware objects and acquisition protocol in order to transmit the sensed data. The network layer helps to support the connections among IoT devices over the different types of networks, such as wireless sensor network and mobile network. The service layer accomplishes the functionality of creating and managing services required by users and provides applications with ready-made services that are available upon request. The interface layer involves interaction techniques or methods, which users and applications can use to interact with the provided services of the service layer. Applying SOA in IoT ensures the availability of the features of extensibility, scalability, modularity, and interoperability among different IoT things [50].

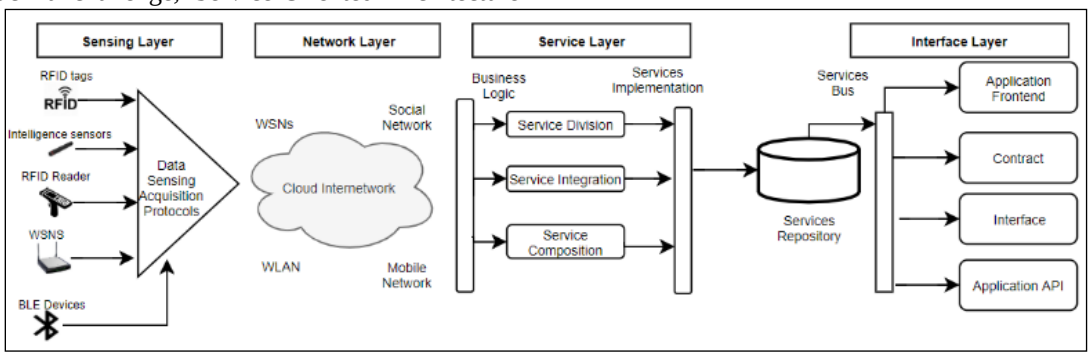

Fig. 13. Service-Oriented IoT Architecture Proposed in 2015[50].

G. IoT Architecture in 2016

In 2016, the focus of IoT architecture was on considering the existence of security. In [46], Salman et al. proposed an IoT architecture with features of data decentralization and control centralization. This architecture, shown in Fig. 14, is formed of four layers: the device layer, the network layer, the control layer, and the application layer.

Starting from the bottom, the device layer includes different types of identification device of things, such as RFID and sensors. In addition, it includes communication technologies like Bluetooth. Network layer performs data transmission that was received from the device layer. Many network types can be used in this layer, including wireless sensor network (WSN), Vehicle area network (VANET), legacy network, and mobile networks, such as second-generation (2G), third-generation (3G), and Long-Term Evolution (LTE). Software-defined gateway (SD-Gateway) is the most useful component of the network layer of this architecture because it facilitates the interoperability among the different types of communication protocol, plus the communication between different networks.

Moreover, SD-Gateway provides many important functions such as firewall, packet encapsulation, and decapsulation, network address translation (NAT), enabling data storage through fog computing, and packet forwarding. The idea of this architecture was to distribute the computing power between cloud and fog nodes, which are located on the edge of SD-Gateway. This kind of distribution will tackle power consumption issues that arise when all data computation is done in SD-Gateway, and network unavailability when data computation is done in the central server (cloud). An intelligent algorithm is needed to decide which kind of data must be stored or saved locally in fog nodes, which sort of data has to be transmitted to cloud, and which type of data need to be deleted. The control layer performs all the computation and involves routing algorithms, scheduling algorithm, and defining the security rules. The central control will lead to scalability limitation and can affect the security enhancement of this architecture. In the application layer, a different IoT application can be implemented. The control layer offers the benefit where the same applications can be deployed on a different SD-Gateway. Different types of management can be performed by this layer, for example, quality of service (QoS), security, privacy, and data analysis [40].

H. IoT Architecture in 2017

In 2017, a four-layer of secured IoT architecture was discussed by Adat and Gupta in [49]. It is mainly composed of four layers: the perceptual layer, the network layer, the support layer, and the application layer, as depicted in Fig. 15.

Fig. 15 illustrates that the perceptual layer is used to collect a different kind of data through physical devices and sensors. The network layer achieves information or data transmission from the perceptual layer to the processing unit. In the support layer, intelligent data operations and processing are executed. The top-most layer (the application layer) deals with end-users. This layer caters for consumers' needs by incorporating users' need in the applications. In this architecture, the analysis of security features in each level or layer was discussed, along with the security requirements, which are necessary to meet the security concerns at each layer. As Adat and Gupta discussed, the main challenges in the perceptual level are devices resource constraints, devices can be exposed to different Denial of service attack (DoS), interferences among devices, issues of confidentiality, integrity, availability (C-I-A) of sensed data at this layer. They suggested that, in order to avoid such challenges in the perceptual layer, the mechanisms of lightweight encryptions, protection of sensed data, and key agreement have to be implemented and applied. In the network layer, Adat and Gupta point out that the main challenges are congestion in the network, eavesdropping, and counterfeiting of the transmitted data, junk emails, and viruses, distributed denial of service attack (DDoS). The key defensive mechanisms for such threats are encryption techniques, anti-DDoS, and communication security. In the control layer, the major issues are intelligent massive processing of data and the filtration of suspicious information. The key solutions for these issues are using techniques to secure multiparty communication and secure computing. The main challenges in the application layer are data privacy and information leakage, application-dependent challenges, and control of access. To address such issues, the privacy protection and security education and management have to be considered [106].

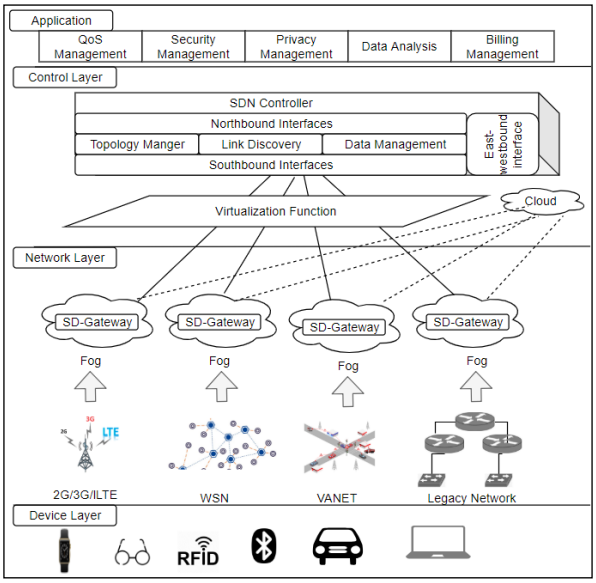

Fig. 14. Centralized Data and Decentralized Control IoT Architecture [40].

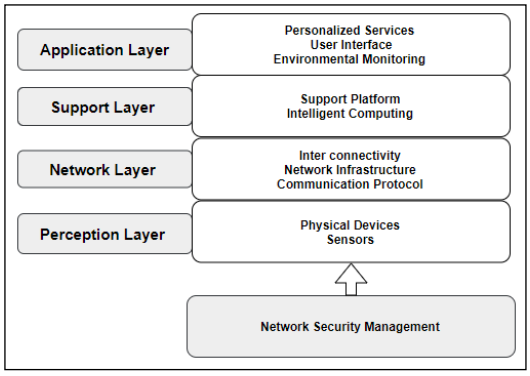

Fig. 15. Four-Layer of Secure IoT Architecture [43].

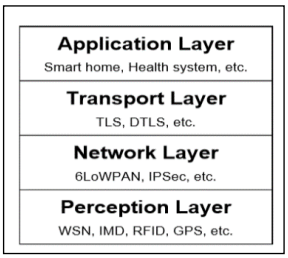

Fig. 16. Four-Layer IoT Architecture [107].

Concurrent with this layer, another four-layer IoT architecture was proposed in [107] by Yuchen et al. The security issues and solutions in each layer were also discussed. The four layers of this architecture are illustrated in Fig. 16.

At the perception layer, various devices are used to collect data, including sensors used to sense temperature, sounds, vibrations, movements, pressure, etc. According to this architecture, this layer is divided into two parts: the perception node and the perception network. The perception node is used for data acquisition, and includes things such as sensors, controllers, etc., while the perception network can be a node that has the ability to communicate and send the obtained data to the gateway [108]. This layer includes technologies such as WSN, implantable medical devices (IMDs), RFID, Global Positioning System (GPS), etc. Several issues were discussed in this layer, as the physical attack on sensor nodes that may lead to destroying or disabling the node. To avoid such attack, QoS should be ensured by having the capability to detect the faulty node and to take actions to minimize the degradation of the service. In the network layer, Yuchen et al suggested using lightweight mobile IPv6 and IPsec as mentioned in [109], since they are the best IoT solution in terms of security and efficiency. In the transport layer, Yuchen et al suggested implementing the two-way communications between IoT devices, such as Datagram Transport Layer Security (DTLS) protocol as discussed in [110]–[112], which provides full authentication DTLS handshake based on the exchange of X.509 certificates that include RSA keys. In the application layer, a variety of applications can be developed, such as smart homes, real-time health monitoring, energy management, environmental monitoring, smart parking, and many other applications. Through these applications, several threats can be noticed and there is an inevitable need to develop standards and security policies for IoT products [107].

Addressing scalability and management issues in IoT is crucial. A new architecture was proposed in 2017 for the purpose of addressing the scalability and management issues based on transparent computing in [42] by Hui et al. This architecture is composed of five layers, as shown in Fig. 17.

As is shown in Fig. 17, the first layer is the end-user layer, which consists of many IoT devices such as PC, Pad, Phones, Vehicle, Sensors, etc. These devices install MetaOS to support the cross-platform and execution of dynamic services. The installed MetaOS can assist them to boot many OSes from the upper layer (edge network layer), by network protocol through different lightweight terminals, which lead to scalability in IoT. Edge network layer has devices, such as a high-performance router and small-scale server that are used to collect and process the data of users, which are collected from the end-user layer. In this layer, the data will be sent to the upper layer (service and storage layer) through the core network layer that forms a bridge between the network layer and the service and storage layer. The service and storage layer has many servers, such as data server, software server, and control server. The main function of the data server is to store the data collected from the lower layer of analytical processing. The software server is responsible for storing the applications and program files of the OSes of the IoT devices and edge devices. The control server is used for managing the two servers (software and data). The management layer manages the servers in the service and storage layer and gives the control server tasks or duties that include adding or updating software. Transparent computing in this architecture is useful for improving the scalability of IoT apps, by logically splitting the hardware and software of IoT devices. This architecture is effective and efficient as the conducted experiment showed [42].

I. IoT Architecture in 2018

Recently, Blockchain was integrated into IoT to solve the challenges related to IoT device management. New IoT architecture was proposed in 2018 to provide a decentralized access control system connected to a distributed sensor network. The architecture was composed of six components which are wireless sensor network, managers, agent node, smart contract, Blockchain management, and management hub [132] as illustrated in Fig. 18.

In this architecture, a wireless sensor network includes IoT devices. As seen in Fig .16, IoT devices do not belong to the blockchain network. The manager has the responsibility to manage the access control permission of a set of IoT devices. The agent node is a specific Blockchain used to deploy smart contact in the system. The access management system is governed by the operations defined in a single smart contract, which is unique and cannot be deleted. The Blockchain network proposed in this architecture is a private network. Management hub is used to translate the information encoded by in CoAP messages by the IoT devices into JSON- RPC messages to be understood by Blockchain node. The proposed architecture addressed the issue of scalability problem of managing billions of IoT devices [113].

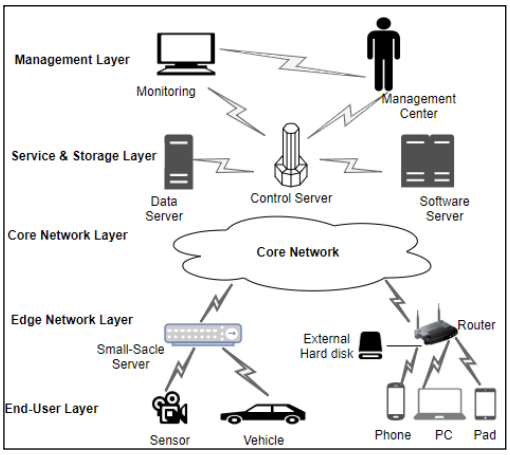

Fig. 17. A Scalable and Manageable IoT Architecture based on Transparent Computing [42].

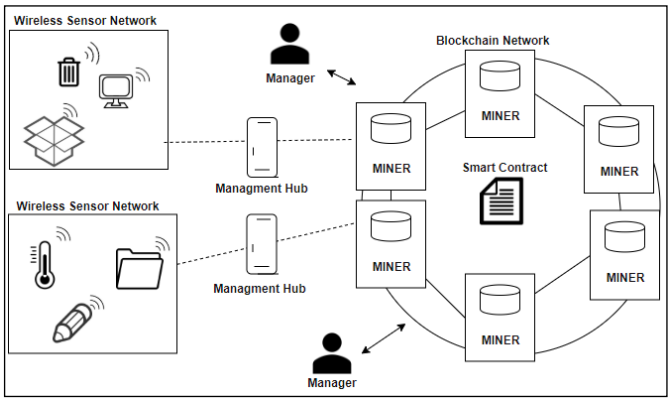

Fig. 18. Blockchain Meets IoT: the Architecture for Scalable Access Management in IoT [113].

In 2018, new IoT architecture was proposed to solve issues such as scalability, efficacy, security, etc. This architecture was based on new technologies such as device-to-device communication, 5G-IoT, Machine-Type Communication (MTC), Wireless Network Function virtualization (WNFV), Wireless Software Defined Networks (WSDN), Mobile Edge Computing (MEC), and Mobile Cloud Computing (MCC). It composed of 8 interconnected layers including Physical device layer that consists of wireless sensors, actuators, and controllers, data communication layer which includes two sublayers (device to device communication, connectivity layer). Fog computing layer, which processes data by edge node to make decisions on data. Data storage layer which stores and protect the obtained information from the edge layer. Management service layer which deals with handling the communication between devices and data centers and it consist of (network management layer, cloud computing layer, and data analytic layer). Application layer that allows software to interact with previous layers and data. Security layer which protects all layers through data encryption, user authentication, network access control, and cloud security [114]. The following Fig. 19. illustrated layers of this architecture.

Another new architecture was proposed in 2018 to tackle challenges of IoT such as scalability, extensibility, interoperability, and integration of heterogeneous devices and protocols. This architecture was based on microservices in the cloud. The architecture uses microelements that involve microservices, which are specific IoT functionalities that can be migrated across various virtualized infrastructure and microdata to exchange across services and devices. In this architecture as depicted in Fig. 20., the microservices is integrated into both edge servers and cloud. Microservices in edge servers supports computation in sensors locally which can save bandwidth for cloud communication. Microservices in cloud server performs Cloudification, virtualization and softwarization, and security of IoT.

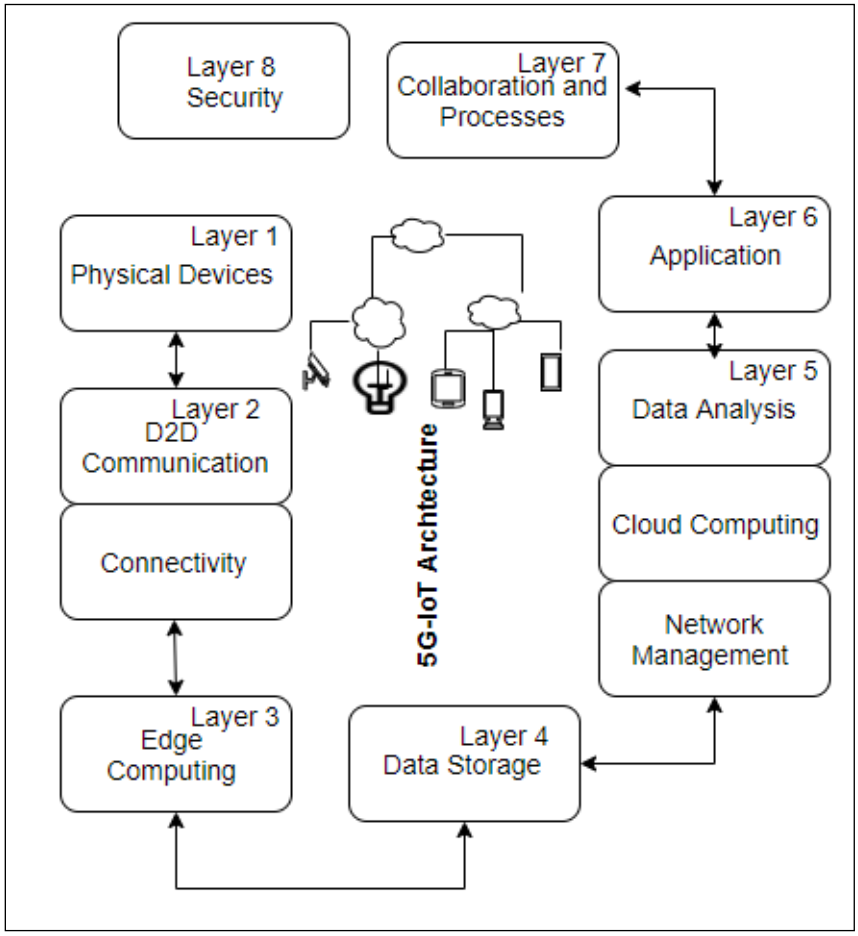

Fig. 19. 5G-IoT Architecture [114].

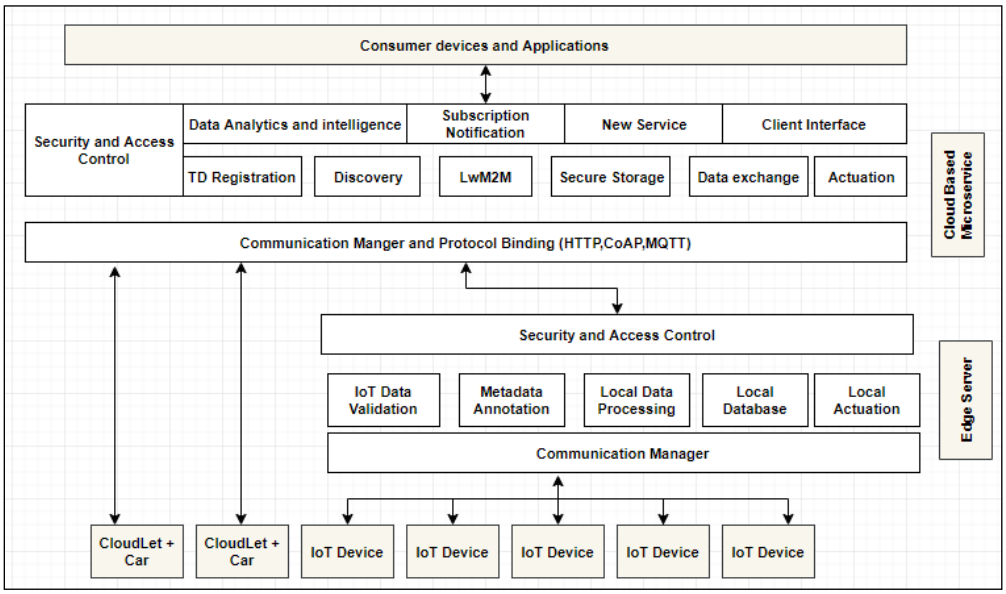

Fig. 20. IoT Architecture based on Microservices [115].

V. Discussion

Table II summarized different IoT architectures that were proposed with the aim of capturing the general essence of IoT technology. All the existing IoT architectures describe the IoT layers. Some architectures are very generic, in which they only describe the IoT layers in an abstract way (e.g. architectures proposed in 2008 and 2010), whereas architectures proposed after 2010 give more details of each layer. However, by comparing all these architectures, it became clear that the earliest architectures, which were proposed at the initial stage of IoT development, have some limitations. For example, the IoT architecture proposed in 2008 in [35], [105], did not consider the storage and processing in their layers. It is well known that data collection is the main functionality of IoT devices. Thus, the collected data need to be processed and stored, in order to be presented or disseminated to the users. In other words, the flow of the data collected by IoT devices was not depicted in this architecture. The architecture that was proposed in 2010 added more description to the previous IoT architecture, in which the storage and the processing layers were introduced. The architectures proposed after 2010 described the comprehensive meaning of IoT, starting from the data collection layer, followed by the network layer, then the processing layer, and ending with the application layer. As shown in Table 2, until 2011, none of the IoT architectures considered security. Table 2 shows the number of IoT devices that reached 12.5 billion in 2010, which resulted in increased concerns related to security issues that threaten IoT. Accordingly, the IoT architecture proposed in 2011 started considering security in IoT layers. It discussed security techniques that can help to decrease the potential risks of the network that may occur due to the access of untrusted users. This architecture was based on a summary of former scholars' research that combined security requirements and IoT characteristics. Scalability and interoperability issues of IoT were considered by the IoT architectures that were proposed in 2014 and 2105. Cloud computing was integrated into IoT architecture to provide a solution for scalability challenge in IoT. Whereas, service originated architecture (SOA) was integrated into IoT architecture to avoid interoperability issues that may occur due to the heterogeneous IoT devices. From 2016 onward, scholars paid more attention to the security issues in IoT. Architectures proposed during this period discussed all the security issues and challenges in each IoT layer, and some recent architectures proposed in 2017 include more details regarding the threats and requirements, and how to deal with such threats. As noticed in architectures which were proposed recently in 2018, different technologies such as Blockchain, 5G, and microservices in the cloud were used to mitigate the challenge of scalability in IoT.

Regarding the consideration of security and privacy aspects in IoT architectures, the findings showed that the existing IoT architectures lack security and privacy aspects. As presented in Table II, none of these architectures considered privacy preservation in IoT. Similar to other technologies, data is the main component of IoT. The data collected by sensors is stored, processed, and presented to users at the end. Therefore, in each IoT layer, there is an inevitable need to secure data and preserve users' privacy. Security in IoT can be achieved by applying security mechanisms, such as encryption and authentications, as pointed out recently by many scholars in [7], [7], [11], [43], [107]. The pervasive nature of IoT imposes many threats that affect individuals' privacy [116]. In IoT, data collection, data storage, data processing, and data representation increase privacy concerns[117]. Many privacy preservation techniques were used for preserving data generated by many technologies, including data mining, data publishing, and wireless sensor network, which were discussed in [118], [119], [128]–[130], [120]–[127]. Recently, scholars have started paying more attention to privacy issues in IoT, as discussed in [131]–[133]. Considering privacy in IoT architecture layers is necessary to preserve users' privacy, which contributes to the sustainability of IoT technology.

TABLE II. COMPARISONS BETWEEN THE EXISTING IOT ARCHITECTURES

IoT Architecture Evolution			**Comparison Criteria**		**Consideration of critical issues**	
Architecture Reference	Year	Architecture Stack	Covered issues(IoT challenges)	Used Technique	Security	Privacy
IoT Five-layer Architectures [105][35]	2008	1. Application Layer 2. Middleware Layer 3. Internet Layer 4. Gateway Layer 5. Edge technology	Didn't consider any IoT challenges. It only describes the main IoT architecture's components.	-	×	×
IoT Five-layer Architectures [35]	2010	1. Application Layer 2. Middleware Layer 3. Coordination Layer 4. Backbone Network 5. Edge Technology Layer	It considered the issue of packet recognition from different apps and traffic and storage.	Perform tasks in the coordination layer and network layer for restructuring packages and reassembling them to form a unified structure.	×	×
IoT Three-layer Architectures [5]		1. Application Layer 2. Network Layer 3. Perception Layer	It was the accepted three-layer structure of IoT. But it cannot express all of the features and connotation of IoT.	-	×	×
IoT Five-layer Architectures [5]		1. Business Layer 2. Application Layer 3. Processing Layer 4. Transport Layer 5. Perception Layer	It considered data storage and processing issue and it added processing and business layer.	Many advanced technologies are used in the processing layer such as: Intelligent processing Cloud computing Ubiquities computing	×	×
General Architecture Of Trusted Security System Based on IoT [36]	2011	1. Trusted user module 2. Trusted perception module 3. Trusted network module 4. Trusted terminal module 5. Trusted Agent Module	It considered important features such as integration, management, supervision of many resources of information security.	To achieve security; authentication mechanism, access control mechanism, encryption mechanism, and audit mechanism were used.	✓	×
IoT Architecture Based on Integrated PLC and 3G Communication Networks [37]		1. Application Layer 2. Network Layer 3. Aggregation Layer 4. Perception Layer	It considered scalability issues.	Combining two types of complex communication networks: PLC and 3G, which offers low cost, convenience, and more reliable services.	×	×
IoT Five-layer Architectures [18]	2012	1. Business Layer 2. Application Layer 3. Middleware Layer 4. Network Layer 5. Perception Layer	It considered the larger traffic and storage needed for data generated by IoT where it focuses on network layer and middleware layer.	Techniques of ubiquities computing, database, information processing, service management, and decision unit are used in the middleware layer.	×	×
Common Architecture for Integrating the Internet of Things with Cloud Computing [38]	2013	1. CloudThings service platform(IaaS) 2. CloudThings developer suite(PaaS) 3. CloudThings operating Portal(SaaS)	It considered integration issue through integrating cloud computing into IoT assist in developing IoT application; it helps to develop, run and deploy Things app online.	Three modules of cloud computing were used: IaaS, PaaS, and SaaS with a set of tools in each module.	×	×

Service-oriented Architecture of IoT [50]	2014	1. Sensing Layer 2. Network Layer 3. Service Layer 4. Interface Layer	It considered heterogeneity, interoperability among heterogeneous IoT devices.	Service Oriented Architecture (SOA)	✗	✗
Decentralized Data and Centralized Control IoT architecture [40]	2105	1. Application Layer 2. Control Layer 3. Network Layer 4. Device Layer	It considered security through SD-Gateway.	SD-Gateway used techniques of: ▪ Firewall ▪ packet encapsulation ▪ Decapsulation ▪ Network Address Translation (NAT). ▪ Fog computing, ▪ Packet forwarding. In the application layer, they introduced privacy management and security management.	✓	✗
Four-layer of secured IoT architecture [107]	2017	1. Application Layer 2. Support Layer 3. Network Layer 4. Perception Layer	It theoretically discussed security challenges in all IoT layers.	The author suggested using lightweight encryption and protection of sensed data.	✓	✗
Four-layer IoT architecture [43]		1. Application Layer 2. Transport Layer 3. Network Layer 4. Perception Layer	It theoretically discussed security issues and solutions in each layer.	The author suggested using Lightweight mobile IPv6 and IPsec to provide security in the network layer. And to use DTLS protocol in the transport layer.	✓	✗
A scalable and manageable IoT architecture based on transparent computing [42]		1. Management Layer 2. Server & Storage Layer 3. Core Network Layer 4. Edge Network Layer 5. End-User Layer	It considered scalability and management issues.	It used transparent computing by logically splitting the hardware and software of IoT devices.	✗	✗
Blockchain meets IoT: an architecture for scalable access management in IoT [113]	2018	1. Wireless Sensor Network 2. Managers 3. Agent Node 4. Smart Contract 5. Blockchain Network 6. Management Hubs	It considered the scalability issue.	Integrating Blockchain in IoT for managing billions of IoT devices through decentralized access control system.	✓	✗
5G-IoT architecture [114]		1. Physical Devices Layer 2. Communication Layer 3. Edge Computing 4. Data Storage Layer 5. Management Service Layer 6. Application Layer 7. Collaboration and Processes Layer 8. Security Layer	It considered issues such as scalability, efficacy, security, etc.	New technologies were used such as a device to device communication, 5G-IoT, Machine-Type Communication(MTC), Wireless Network Function virtualization (WNFV), Wireless Software Defined Networks (WSDN), Mobile Edge Computing (MEC), and Mobile Cloud Computing (MCC)	✓	✗
IoT Architecture Based on Microservices [115]		1. Consumer devices and application 2. Cloudbased microservices 3. Edge server microservices	It solved issues such as scalability, efficacy, security, etc.	The technology of microservices in the cloud was used in edge server to support computation in sensors and in the cloud to perform services such as security, virtualization, etc.	✓	✗

VI. Conclusion

As technology evolves, new concepts emerge in the technology world that adds new advanced features to serve the world with influential solutions. This paper presented a systematic literature review to study the existing IoT architectures in terms of architecture classification (the number of layers), limitations in each architecture, and considerations of different aspects or features in each layer such as storage, processing techniques, security, and privacy. The findings show that the improvement of IoT architectures occurred gradually as technology evolved. In addition, the initial IoT architectures were very abstract and did not provide a comprehensive meaning of IoT nature. On the other hand, late architectures focused more on the essence of IoT and concentrated on how the data can be transferred, stored, and transmitted to the consumer. Different supporting technologies were considered in each layer of the different IoT architectures. The consideration of the security aspect in IoT architecture started in 2011. Overall, it was clearly noticed that none of these architectures has considered privacy preservation in IoT. Considering privacy in IoT architectures is very important for users to accept the IoT technology. Thus, there is an inevitable need to address privacy issues in IoT, which is considered a key factor in the sustainability of IoT development. The research will be extended to consider user privacy in all IoT architecture layers, by integrating privacy mechanisms in IoT architecture layers.

VII. Research Direction

Efforts must be devoted to integrating privacy preservation mechanisms when designing an IoT architecture, with the aim of preserving the privacy of users on one side and providing quality services on the other side. Privacy issues should be addressed at every IoT stage or level to avoid any attack that may compromise the data and, thus, influence the trust of users which could impact IoT sustainability.

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Complex Binary Adder Designs and their Hardware Implementations

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***Abstract*—Complex Binary Number System (CBNS) is (-1+j)-based on binary number system which facilitates both real and imaginary components of a complex number to be represented as single binary number. In this paper, we have presented three designs of nibble-size complex binary adders (ripple-carry, decoder-based, minimum-delay) and implemented them on various Xilinx FPGAs. The designs of base2 4-bit binary adder have also been implemented so that statistics of different adders can be compared.**

***Keywords*—Complex number; complex binary; adder; ripple carry; decoder; minimum delay**

I. Introduction

Complex numbers play important roles in various areas of electrical and computer engineering but their representation and treatment in the realm of computing are based on a *divide-and-conquer* technique wherein real part of the complex number is dealt with separately and imaginary part of the complex number is handled separately. Thus, addition of two complex numbers (a+jb) and (c+jd) involves two separate additions: (a+c) for the real parts and (b+d) for the imaginary parts. To facilitate single-unit representation of a complex number which will ultimately result in the reduction of arithmetic operations for the real and imaginary components of complex numbers, Complex Binary Number System (CBNS) with (-1+j)-base has been proposed in the scientific literature [1-4]. In this paper, we are going to present three designs of nibble-size complex binary adder circuits and their implementations on various Xilinx FPGAs. For the sake of comparison, we'll also present implementation of base2 nibble-size adder so that relative complexity of different adder designs can be appreciated.

II. Complex Binary Number System

A. Binary Representation

The value of an n-bit binary number with base (-1+j) can be written in the form of a power series as follows: $a_{n-1}(-1+j)^{n-1} + a_{n-2}(-1+j)^{n-2} + a_{n-3}(-1+j)^{n-3} + \ldots + a_2(-1+j)^2 + a_1(-1+j)^1 + a_0 (-1+j)^0$ where the coefficients $a_{n-1},a_{n-2},a_{n-3},\ldots,a_2,a_1,a_0$ are binary (either 0 or 1). This is analogous to the ordinary binary number system power series of $a_{n-1}(2)^{n-1} + a_{n-2}(2)^{n-2} + a_{n-3}(2)^{n-3} + \ldots + a_2(2)^2 + a_1(2)^1 + a_0 (2)^0$ except that the bases are different. Details about how to convert a given complex number into (-1+j)-base complex binary number representation can be found in [1-4]. By the application of the conversion algorithms mentioned in these publications, a given complex number can be represented as a single binary entity. For example, the complex number 2019+j2019 has the binary representation in base (-1+j) as: 1110100000001110100001100110.

B. Addition Algorithm

The binary addition of two complex binary numbers follows these rules: 0 + 0 = 0;0 + 1 = 1; 1 + 0 = 1; 1 + 1 = 1100. These rules are very similar to the traditional binary arithmetic except for the last case when two numbers with 1s in position *n* are added, this will result in 1s in positions *n+3* and *n+2* and 0s in positions *n+1* and *n* in the sum. Similar to the ordinary computer rule where 1+111 … (to limit of machine) =0, we have 11 + 111 = 0 [Zero Rule].

III. Adder Designs

A. Ripple-Carry

The block diagram of a 4-bit Complex Binary Ripple-Carry Adder (CBRCA) is shown in Fig. 1 [5].

The adder performs the addition of two 4-bit complex binary numbers A ($a_3a_2a_1a_0$) and B ($b_3b_2b_1b_0$) and generates a 4-bit (-1+j)-radix result (Sum) and up to 8 Extended-Carries. It consists of the Addition Unit, the Extended-Carry Generation Unit, the Zero Detection Unit, and the Output Generation Unit.

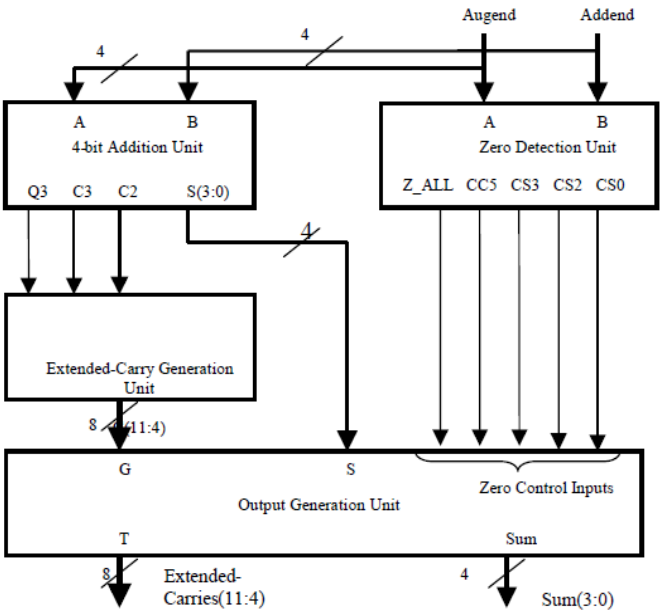

Fig. 1. Block Diagram of a 4-bit Complex Binary Ripple-Carry Adder [5].

The Addition Unit is structured from 4 semi-cascaded stages. Each stage is responsible of generating one of the bits of the result *(S_0-S_3)*. The carry generated from the addition of two bits in (-1+j) radix representation at stage *i* produces a carry that should be propagated to stages *i+2* and *i+3*. Since no carry-in(s) to the adder is assumed, stages 0 and 1 are easily implemented using two half-adders. Stage 2 is implemented using a full-adder with a carry-in generated from stage 0. While for stage 3, a specially designed 4-input binary variables adding component is implemented [6]. Stage 3 performs the addition of bits b_3 and a_3 of the Addend and Augend with possible two carries referred to by K_{31} and K_{32}, which may be generated from stages 0 and 1, respectively. Stage 3 produces bit S_3 of the result and two carry bits, C_3 and Q_3, according to the 4 binary variables truth table for the addition stage. C_3 is a normal carry due to adding three ones (1+1+1), and Q_3 is an extended carry due to adding four ones (1+1+1+1) in (-1+j) radix representation. C_3 should propagate to stages 5 and 6, and Q_3 to stages 7, 9, 10, and 11. Since the adder performs 4-bit (-1+j)-base complex number addition, the carries C_2, C_3, and Q_3 are taken to the inputs of the Extended-Carries unit, in order to generate all the necessary carries. All carries generated by stages 2 and 3 are handled by dummy stages in the Extended-Carry Generation Unit, referred to by stages 4 to 11. Each stage of the Extended-Carries Unit is responsible of generating one Extended-Carry bit. The Boolean equations for stages 0, 1, and 2 are obvious from the use of half-adders and full-adder circuits. For stage 3, the Boolean equations of the outputs are found from the minimization of 4-variable Karnaugh maps. These are,

$$S_3 = a_3 \oplus b_3 \oplus K_{31} \oplus K_{32} \tag{1}$$

$$C_3 = \bar{a}_3 K_{31} K_{32} + b_3 K_{31} \bar{K}_{32} + a_3 \bar{b}_3 K_{31} + a_3 \bar{K}_{31} K_{32} + a_3 b_3 \bar{K}_{31} + b_3 \bar{K}_{31} K_{32} \tag{2}$$

$$Q_3 = a_3 b_3 K_{31} K_{32} \tag{3}$$

The S_3 expression is a 4-input odd function that can be implemented by EXCLUSIVE-OR gates, the Q_3 expression is a 4-input AND function, and the C_3 is a sum-of-product expression that can be implemented by a two-stage logic (e.g., AND-OR, or NAND-NAND).

The Extended-Carry Generation Unit consists of 8 dummy stages, 4-11. They handle the propagated carries from stages 2 *(C_2)* and 3 *(C_3, Q_3)* in the Addition Unit. The Dummy stages 4, 5, 6, and 8 are implemented using half adders, and dummy stages 7, 9, 10, and 11 are implemented using full-adders. The unit would generate the extended carries *(C_4-C_{11})* as inputs to the Output Generation Unit.

The Zero Detection Unit determines the conditions necessary to generate special output results based on the recognition of specific patterns for the Addend and the Augend. All conditions considered are based on the Zero Rule for the (-1+j) radix number representation. Assuming 4-bit (-1+j) radix numbers, the unit receives inputs for the Addend *(b_3 b_2 b_1 b_0)* and the Augend *(a_3 a_2 a_1 a_0)*, and generates five control signals: *CS0*, *CS1*, *CS3*, *CC5*, and *Z_ALL*. The five control signals are generated based on the patterns detected for the Addend *($b_3b_2b_1b_0$)* and the Augend *($a_3a_2a_1a_0$)*, which satisfy the Zero Rule. Table 1 lists all the minterms of the input that will generate special output results.

The Boolean expressions characterizing each control output are defined below.

1) CS0 Control Output: CS0 controls the summation bit S_0 according to table 1. Its Boolean expression is described as:

$$CS0 = \sum(111, 126, 231, 239, 246, 254)$$
$$CS0 = (a_2\, a_1\, b_2\, b_1)(\overline{a_0}\, b_3\, b_0 + a_0\, b_3\, \overline{b_0} + a_3\, b_3\, (a_0 \oplus b_0)) \tag{4}$$

2) CS2 Control Output: CS2 controls the summation bit S_2 according to table 1. Its Boolean expression is described as:

$$CS2 = \sum(119, 127, 247, 255)$$
$$CS2 = (a_2\, a_1\, a_0\, b_2\, b_1\, b_0) \tag{5}$$

3) CS3 Control Output: CS3 controls the summation bit S_3 according to table 1. Its Boolean expression is described as:

$$CS3 = \sum(63, 123, 127, 183, 238, 239, 243, 247, 254)$$
$$CS3 = (a_1\, b_1)(\overline{a_3}\, a_0\, b_3\, b_2\, b_0 + a_3\, a_0\, \overline{b_3}\, b_2\, b_0 + a_3\, a_2\, b_3\, b_2\, \overline{b_0} + \overline{a_3}\, a_2\, a_0\, b_3\, b_0 + a_3\, a_2\, a_0\, \overline{b_3}\, b_0 + a_3\, a_2\, \overline{a_0}\, b_3\, b_2) \tag{6}$$

4) CC5 Control Output: CC5 controls the extended carry bits C_5 *and* C_6 according to table 1. Its Boolean expression is described as:

$$CC5 = \sum(191, 251, 255)$$
$$CC5 = (a_3\, a_2\, a_1\, a_0\, b_3\, b_1\, b_0 + a_3\, a_1\, a_0\, b_3\, b_2\, b_1\, b_0) \tag{7}$$

5) Z_ALL Control Output: Z_ALL controls generating all zeros in the sum and extended carry bits according to Table 1. Its Boolean expression is described as:

$$Z\_ALL = \sum(55, 110, 115, 230)$$
$$Z\_ALL = (a_1\, b_1)(\overline{a_3}\, a_0\, \overline{b_3}\, b_0\, (a_2 \oplus b_2) + a_2\, \overline{a_0}\, b_2\, \overline{b_0}\, (a_3 \oplus b_3)) \tag{8}$$

The Output Generation Unit receives the control signals, *(CS0, CS2. CS3, CC5, Z_ALL)*, from the Zero Detection Unit, the result of addition *(S_0-S_3)* and the extended-carries *(C_4-C_{11})*. Then it determines the actual Sum bits *(Sum_0-Sum_3)* and the actual Extended-Carry bits *(T_4-T_{11})* according to the control signals described above.

B. Decoder-Based

The design of a nibble-size decoder-based adder involves the following steps[7]: (i) Generation of a truth table with two 4-bit operands --- operand A with $a_3a_2a_1a_0$ bits and Operand B with $b_3b_2b_1b_0$ bits --- addition of these two operands produces twelve outputs which are labeled as $c_{11}c_{10}c_9c_8c_7c_6c_5c_4s_3s_2s_1s_0$.

The truth table (Table 2) has a total of 2^8 = 256 minterms. (ii) We have used a 8x256 decoder to implement this truth table. For this purpose, we expressed each output in sum-of-minterms form as shown on the next page. (iii) Finally, these expressions have been implemented using the decoder and OR gates as shown in Fig. 2.

TABLE. I. APPLICATION OF THE ZERO RULE TO 4-BIT ADDITION OPERANDS

MINTERM (Dec.)	$a_3a_2a_1a_0b_3b_2b_1b_0$ (Hex.)	$C_{11}C_{10}C_9C_8C_7C_6C_5C_4$ (Hex.)	$S_3S_2S_1S_0$ (Hex.)
55	37	00	0
63	3F	00	8
110	6E	00	0
111	6F	00	1
115	73	00	0
119	77	00	4
123	7B	00	4
126	7E	00	1
127	7F	00	C
183	B7	00	8
191	BF	06	0
230	E6	00	0
231	E7	00	1
238	EE	00	8
239	EF	00	9
243	F3	00	8
246	F6	00	1
247	F7	00	C
251	FB	06	0
254	FE	00	9
255	FF	06	4

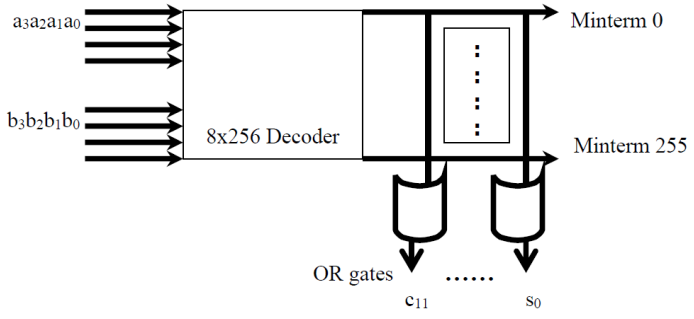

Fig. 2. Block Diagram of a 4-bit Complex Binary Complex Binary Adder using Decoder.

$c_{11} = \Sigma$ (187) $c_{10} = \Sigma$ (187) $c_9 = \Sigma$ (187)

$c_8 = \Sigma$ (29,31,61,89,91,93,95,121,125,149,151,157,159,181,189, 204,205,206,207,209,211,213, 215,217, 219,220,221,222,223, 236,237,241,245,249,252,253)

$c_7 = \Sigma$ (29,31,61,89,91,93,95,102,103,118,121,125,149,151,157, 159, 181,187,189,204, 205,206,207,209,211,213,215,217,219, 220,221,222,223, 236,237,241, 245,249,252,253)

$c_6 = \Sigma$ (25,27,29,31,42,43,46,47,51,57,58,59,61,62,89,91,93, 95,102,103,106,107,118,121,122,125,136,137,138,139,140, 141,142,143,145,147,149,151,152,153,154,155,156,157,158, 159,162,163,166,167,168, 169,170,171,172,173,174,175,177, 178,179,181,182,184,185,186,188,189,190,191,200,201,202, 203,204,205,206,207,209,211,213,215,216,217,218,219,220, 221, 222,223,226, 227,232,233,234,235,236,237,241,242,245, 248,249,250,251,252, 253,255)

$c_5 = \Sigma$ (21,23,25,27,42,43,46,47,51,53,57,58,59,62,68,69,70, 71,76,77,78,79,81,83,84,85,86,87,92,94,100, 101,102,103, 106,107,108,109,113,116,117,118,122,124,136,137,138,139, 140,141,142,143,145,147,152,153,154,155,156, 158,162, 163,166,167,168,169,170,171,172,173,174,175,177,178,179, 182,184,185,186,188,190,191,196,197,198,199,200, 201,202, 203,212, 214,216, 218,226,227,228, 229,232,233,234,235, 242,244,248,250,251,255)

$c_4 = \Sigma$ (21,23,29,31, 34,35,38,39,42,43,46,47,50,51,53,54,58, 59,61,62,68,69,70,71,76,77,78,79, 81,83,84,85,86,87,89,91,92, 93,94,95,98,99,100,101,106,107,108,109,113,114,116,117, 121,122,124,125,149,151,157,159,162,163,166,167,170,171, 174,175,178,179, 181,182,186,187,189,190, 196,197,198, 199,204,205,206,207,209,211,212,213,214,215,217,219,220, 221, 222, 223,226,227, 228,229,234,235,236,237,241,242, 244,245,249,250,252,253)

$s_3 = \Sigma$ (8,9,10,11,12,13,14,15,17,19,21,23,24,26,28,30, 34,35, 38,39,40,41,44,45,49,50,53,54,56, 59,60,63,72,73,74,75,76, 77,78,79,81,83,85,87,88,90,92,94,98,99,102,103,104,105, 108,109,113,114,117,118,120,123,124,127,128,129,130,131, 132, 133,134,135,144,146,148,150,153,155,157, 159,160,161, 164,165,170, 171,174,175,176,179,180,183,185,186,189,190, 192, 193,194,195,196,197,198,199,208,210,212,214,217,219, 221,223,224,225,228,229,234,235,238,239,240,243,244,247, 249, 250,253,254)

$s_2 = \Sigma$ (4,5,6,7,12,13,14,15,17,19,20,22,25,27,28,30,36,37,38, 39,44,45,46,47,49,51,52,54,57, 59,60,62,64,65,66, 67,72,73, 74,75,80,82,85,87,88,90,93,95,96,97,98,99,104,105,106,107, 112, 114,117,119,120,122,125,127,132,133,134,135,140,141, 142,143,145,147,148,150,153, 155,156, 158,164,165,166,167, 172,173,174,175,177,179,180,182,185,187,188,190, 192,193, 194,195,200, 201,202,203,208,210,213,215,216,218,221,223, 224,225,226,227,232,233,234,235,240,242,245, 247,248,250, 253,255)

$s_1 = \Sigma$(2,3,6,7,10,11,14,15,18,19,22,23,26,27,30,31,32,33,36, 37,40,41,44,45,48,49,52,53,56,57, 60,61,66,67,70,71,74,75, 78,79,82,83,86,87,90,91,94,95,96,97,100,101,104,105,108, 109,112, 113,116,117,120,121,124,125,130,131,134, 135,138, 139,142,143,146,147,150,151,154,155,158,159,160,161,164,

165,168, 169,172,173,176,177,180,181,184,185, 188,189,194, 195,198,199,202, 203,206,207,210,211,214,215,218,219, 222,223,224,225,228,229,232,233,236,237,240,241,244, 245, 248, 249,252,253)

s_0= Σ (1,3,5,7,9,11,13,15,16,18,20,22,24,26,28,30,33,35,37,39, 41,43,45,47,48,50,52,54,56,58,60,62,65,67,69,71,73,75,77,79, 80,82,84,86,88,90,92,94,97,99,101,103,105,107,109,111,112, 114,116,118,120,122,124,126,129,131,133,135,137,139,141, 143,144,146,148,150,152,154,156,158,161,163,165,167,169, 171,173,175,176,178,180,182,184,186,188,190,193,195,197, 199,201,203,205,207,208,210,212,214,216,218,220,222,225, 227,229,231,233,235,237,239,240,242,244,246,248,250,252, 254)

C. Minimum-Delay

The truth table of the 4-bit complex binary adder, given in Table 2, was entered, one output at a time, into online Karnaugh Map [8] and simplified Boolean expression for each output was obtained. To facilitate use of online K-Map, the inputs were labeled as ABCD for the augend and EFGH for the addend. The outputs were labeled as JKLMPRSTUWYZ. The simplified expression for each output was implemented on Xilinx FPGAs and statistics for the circuit were obtained.

The simplified expressions obtained for outputs are:

$$J = K = L = A\overline{B}CDE\overline{F}GH$$

$$M = \overline{C}DEFH + DEF\overline{G}H + B\overline{C}DEH + A\overline{C}DFH + ADF\overline{G}H + AB\overline{C}EF + ABEF\overline{G} + AB\overline{C}DH + ABD\overline{G}H$$

$$P = \overline{C}DEFH + DEF\overline{G}H + B\overline{C}DEH + BDE\overline{G}H + A\overline{C}DFH + ADF\overline{G}H + AB\overline{C}EF + ABEF\overline{G} + AB\overline{C}DH + ABD\overline{G}H + \overline{A}BC\overline{D}EFG + \overline{A}BC\overline{E}FG\overline{H} + A\overline{B}CDE\overline{F}GH$$

$$R = A\overline{C}E + AE\overline{G} + \overline{C}DEH + DE\overline{G}H + A\overline{C}DH + AD\overline{G}H + ABE\overline{F} + \overline{B}C\overline{D}EG + C\overline{D}E\overline{F}G + \overline{B}CEG\overline{H} + CE\overline{F}G\overline{H} + ADEFH + A\overline{B}C\overline{D}G + AC\overline{D}FG + A\overline{B}CG\overline{H} + AC\overline{F}G\overline{H} + A\overline{B}D\overline{E}FH + \overline{A}BCD\overline{F}GH + \overline{A}BC\overline{D}EFG + \overline{A}BC\overline{E}FG\overline{H}$$

$$S = A\overline{B}\overline{D}E + A\overline{D}E\overline{F} + A\overline{B}E\overline{H} + AE\overline{F}\overline{H} + \overline{B}C\overline{D}EG + C\overline{D}E\overline{F}G + \overline{B}CEG\overline{H} + CE\overline{F}G\overline{H} + \overline{A}B\overline{C}\overline{D}F + \overline{A}B\overline{D}\overline{E}F + B\overline{C}\overline{D}\overline{E}F + \overline{A}B\overline{D}F\overline{G} + B\overline{D}E\overline{F}\overline{G} + \overline{A}B\overline{C}F\overline{H} + \overline{A}B\overline{E}F\overline{H} + B\overline{C}\overline{E}F\overline{H} + \overline{A}BF\overline{G}\overline{H} + B\overline{E}F\overline{G}\overline{H} + A\overline{B}\overline{C}E\overline{F} + A\overline{B}E\overline{F}\overline{G} + A\overline{B}C\overline{D}G + AC\overline{D}FG + A\overline{B}CG\overline{H} + AC\overline{F}G\overline{H} + \overline{A}C\overline{D}E\overline{F}H + \overline{A}D\overline{E}\overline{F}\overline{G}H + \overline{A}B\overline{D}E\overline{F}H + A\overline{B}D\overline{E}\overline{F}H + ABCE\overline{F}G + \overline{A}B\overline{C}DF\overline{G}H + \overline{A}B\overline{C}D\overline{E}\overline{G}H + \overline{A}B\overline{C}D\overline{E}GH + \overline{A}BCD\overline{E}\overline{G}H + ACDEFGH$$

$$T = B\overline{C}F + BF\overline{G} + \overline{C}DFH + DF\overline{G}H + \overline{B}C\overline{D}G + \overline{B}C\overline{F}G + C\overline{D}FG + \overline{B}CG\overline{H} + C\overline{F}G\overline{H} + B\overline{C}DGH + B\overline{C}DEH + BCD\overline{G}H + AB\overline{C}DH + \overline{A}B\overline{C}\overline{D}E\overline{G}H$$

$$U = \overline{A}C\overline{D}E + \overline{A}D\overline{E}\overline{G} + \overline{A}C\overline{E}\overline{H} + \overline{A}E\overline{G}\overline{H} + A\overline{C}\overline{D}E + A\overline{D}\overline{E}\overline{G} + A\overline{C}\overline{E}H + A\overline{E}\overline{G}H + \overline{A}C\overline{D}\overline{E}H + \overline{A}D\overline{E}\overline{G}H + \overline{A}C\overline{D}\overline{E}G + \overline{A}C\overline{E}\overline{G}H + A\overline{C}DEH + AD\overline{E}\overline{G}H + AC\overline{D}EG + ACE\overline{G}\overline{H} + \overline{A}CDEGH + ACD\overline{E}\overline{G}H + \overline{A}B\overline{C}DFGH$$

$$W = \overline{B}DF + B\overline{F}\overline{H} + \overline{A}B\overline{F}\overline{H} + \overline{B}E\overline{F}\overline{H} + \overline{B}FG\overline{H} + \overline{B}D\overline{F}H + \overline{B}CF\overline{H} + B\overline{D}FG + B\overline{D}E\overline{F} + BDFH + BC\overline{D}F + AB\overline{D}F + \overline{A}C\overline{D}\overline{E}FGH + A\overline{B}\overline{C}EF\overline{G}H$$

$$Y = \overline{C}G + C\overline{G} + \overline{A}B\overline{C}\overline{E}FH$$

$$Z = D\overline{H} + \overline{B}D\overline{H} + \overline{D}GH + \overline{D}FH + \overline{D}EH + C\overline{D}H + A\overline{D}H + \overline{A}B\overline{C}D\overline{E}FG$$

The logic diagram of minimum-delay complex binary adder is given in Fig. 3.

The logic diagram of each adder output (J,K,L,M,P,R,S,T, U,W,Y,Z) is shown in Figs.4-15.

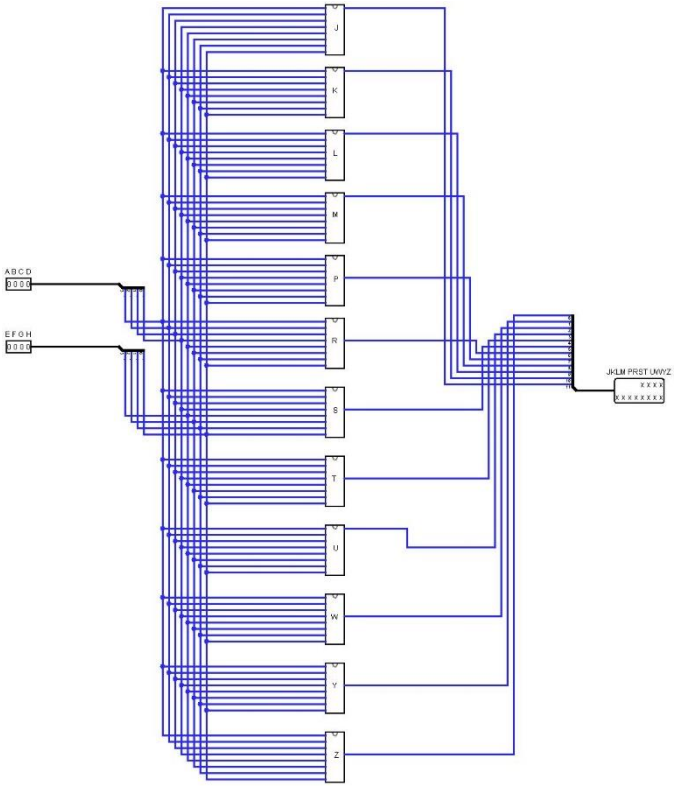

Fig. 3. Block Diagram of a 4-bit Complex Binary Minimum-Delay Adder.

TABLE. II. TRUTH TABLE OF A 4-BIT COMPLEX BINARY ADDER (MINTERM: $A_3A_2A_1A_0$ ADD $B_3B_2B_1B_0 = C_{11}C_{10}C_9C_8C_7C_6C_5C_4S_3S_2S_1S_0$)

0	00000000 00000000000	64	01000000 00000000100
1	00000001 00000000001	65	01000001 00000000101
2	00000010 00000000010	66	01000010 00000000110
3	00000011 00000000011	67	01000011 00000000111
4	00000100 00000000100	68	01000100 00000110000
5	00000101 00000000101	69	01000101 00000110001
6	00000110 00000000110	70	01000110 00000110010
7	00000111 00000000111	71	01000111 00000110011
8	00001000 00000001000	72	01001000 00000001100
9	00001001 00000001001	73	01001001 00000001101
10	00001010 00000001010	74	01001010 00000001110
11	00001011 00000001011	75	01001011 00000001111
12	00001100 00000001100	76	01001100 00000111000
13	00001101 00000001101	77	01001101 00000111001
14	00001110 00000001110	78	01001110 00000111010
15	00001111 00000001111	79	01001111 00000111011
16	00010000 00000000001	80	01010000 00000000101
17	00010001 00000001100	81	01010001 00000111000
18	00010010 00000000011	82	01010010 00000000111
19	00010011 00000001110	83	01010011 00000111010
20	00010100 00000000101	84	01010100 00000110001
21	00010101 00000111000	85	01010101 00000111100
22	00010110 00000000111	86	01010110 00000110011
23	00010111 00000111010	87	01010111 00000111110
24	00011000 00000001001	88	01011000 00000001101
25	00011001 00000100100	89	01011001 00011010000
26	00011010 00000001011	90	01011010 00000001111
27	00011011 00000100110	91	01011011 00011010010
28	00011100 00000001101	92	01011100 00000111001
29	00011101 00011010000	93	01011101 00011010100
30	00011110 00000001111	94	01011110 00000111011
31	00011111 00011010010	95	01011111 00011010110
32	00100000 00000000010	96	01100000 00000000110
33	00100001 00000000011	97	01100001 00000000111
34	00100010 00000011000	98	01100010 00000011100
35	00100011 00000011001	99	01100011 00000011101
36	00100100 00000000110	100	01100100 00000110010
37	00100101 00000000111	101	01100101 00000110011
38	00100110 00000011100	102	01100110 00011101000
39	00100111 00000011101	103	01100111 00011101001
40	00101000 00000001010	104	01101000 00000001110
41	00101001 00000001011	105	01101001 00000001111
42	00101010 00001110000	106	01101010 00001110100
43	00101011 00001110001	107	01101011 00001110101
44	00101100 00000001110	108	01101100 00000111010
45	00101101 00000001111	109	01101101 00000111011
46	00101110 00001110100	110	01101110 00000000000
47	00101111 00001110101	111	01101111 00000000001
48	00110000 00000000011	112	01110000 00000000111
49	00110001 00000001110	113	01110001 00000111010
50	00110010 00000011001	114	01110010 00000011101
51	00110011 00001110100	115	01110011 00000000000
52	00110100 00000000111	116	01110100 00000110011
53	00110101 00000111010	117	01110101 00000111110
54	00110110 00000011101	118	01110110 00011101001
55	00110111 00000000000	119	01110111 00000000100
56	00111000 00000001011	120	01111000 00000001111
57	00111001 00001100110	121	01111001 00011010010
58	00111010 00001110001	122	01111010 00001110101
59	00111011 00001111100	123	01111011 00000001000
60	00111100 00000001111	124	01111100 00000111011
61	00111101 00011010010	125	01111101 00011010110
62	00111110 00001110101	126	01111110 00000000001
63	00111111 00000001000	127	01111111 00000001100
128	10000000 00000001000	192	11000000 00000001100
129	10000001 00000001001	193	11000001 00000001101
130	10000010 00000001010	194	11000010 00000001110
131	10000011 00000001011	195	11000011 00000001111
132	10000100 00000001100	196	11000100 00000111000
133	10000101 00000001101	197	11000101 00000111001
134	10000110 00000001110	198	11000110 00000111010
135	10000111 00000001111	199	11000111 00000111011
136	10001000 00001100000	200	11001000 00001100100
137	10001001 00001100001	201	11001001 00001100101
138	10001010 00001100010	202	11001010 00001100110
139	10001011 00001100011	203	11001011 00001100111
140	10001100 00001100100	204	11001100 00011010000
141	10001101 00001100101	205	11001101 00011010001
142	10001110 00001100110	206	11001110 00011010010
143	10001111 00001100111	207	11001111 00011010011
144	10010000 00000001001	208	11010000 00000001101
145	10010001 00001100100	209	11010001 00011010000
146	10010010 00000001011	210	11010010 00000001111
147	10010011 00001100110	211	11010011 00011010010
148	10010100 00000001101	212	11010100 00000111001
149	10010101 00011010000	213	11010101 00011010100
150	10010110 00000001111	214	11010110 00000111011
151	10010111 00011010010	215	11010111 00011010110
152	10011000 00001100001	216	11011000 00001100101
153	10011001 00001101100	217	11011001 00011011000
154	10011010 00001100011	218	11011010 00001100111
155	10011011 00001101110	219	11011011 00011011010
156	10011100 00001100101	220	11011100 00011010001
157	10011101 00011011000	221	11011101 00011011100
158	10011110 00001100111	222	11011110 00011010011
159	10011111 00011011010	223	11011111 00011011110
160	10100000 00000001010	224	11100000 00000001110
161	10100001 00000001011	225	11100001 00000001111
162	10100010 00001110000	226	11100010 00001110100
163	10100011 00001110001	227	11100011 00001110101
164	10100100 00000001110	228	11100100 00000111010
165	10100101 00000001111	229	11100101 00000111011
166	10100110 00001110100	230	11100110 00000000000
167	10100111 00001110101	231	11100111 00000000001
168	10101000 00001100010	232	11101000 00001100110
169	10101001 00001100011	233	11101001 00001100111
170	10101010 00001111000	234	11101010 00001111100
171	10101011 00001111001	235	11101011 00001111101
172	10101100 00001100110	236	11101100 00011010010
173	10101101 00001100111	237	11101101 00011010011
174	10101110 00001111100	238	11101110 00000001000
175	10101111 00001111101	239	11101111 00000001001
176	10110000 00000001011	240	11110000 00000001111
177	10110001 00001100110	241	11110001 00011010010
178	10110010 00001110001	242	11110010 00001110101
179	10110011 00001111100	243	11110011 00000001000
180	10110100 00000001111	244	11110100 00000111011
181	10110101 00011010010	245	11110101 00011010110
182	10110110 00001110101	246	11110110 00000000001
183	10110111 00000001000	247	11110111 00000001100
184	10111000 00001100011	248	11111000 00001100111
185	10111001 00001101110	249	11111001 00011011010
186	10111010 00001111001	250	11111010 00001111101
187	10111011 11101001010	251	11111011 00001100000
188	10111100 00001100111	252	11111100 00011010011
189	10111101 00011011010	253	11111101 00011011110
190	10111110 00001111101	254	11111110 00000001001
191	10111111 00001100000	255	11111111 00001100100

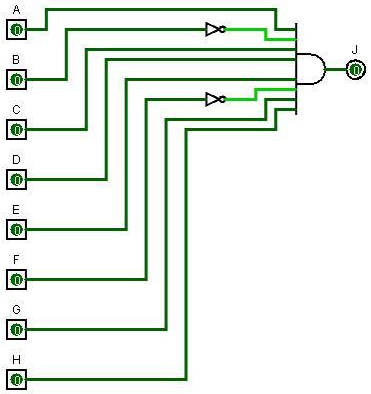

Fig. 4. Logic Diagram for Output J.

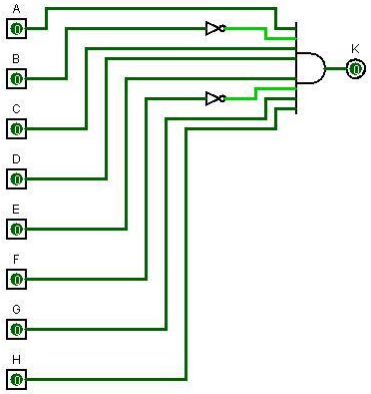

Fig. 5. Logic Diagram for Output K.

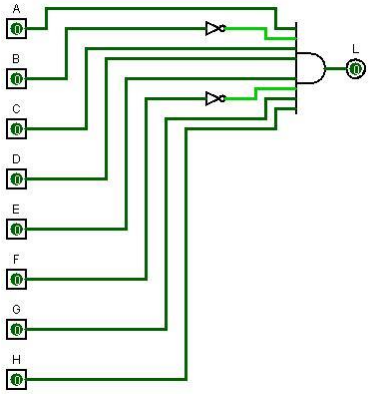

Fig. 6. Logic Diagram for Output L.

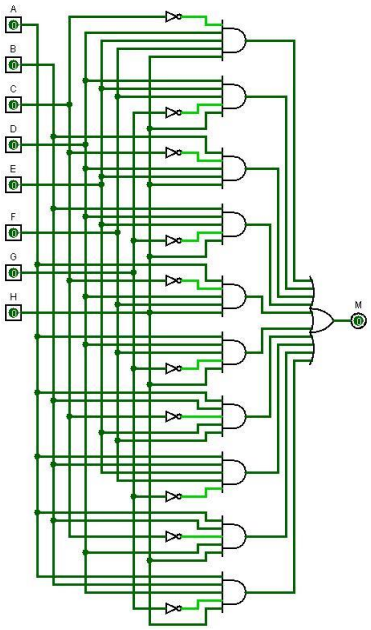

Fig. 7. Logic Diagram for Output M.

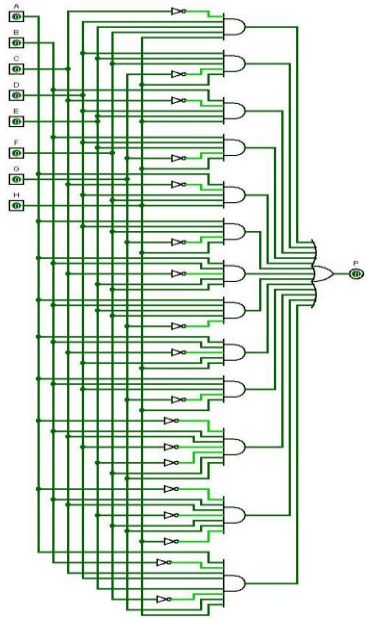

Fig. 8. Logic Diagram for Output P.

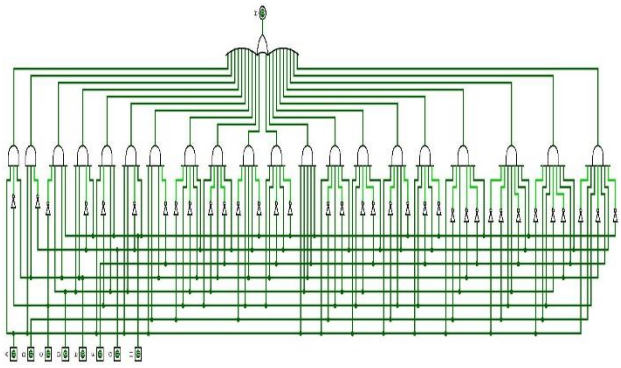

Fig. 9. Logic Diagram for Output R.

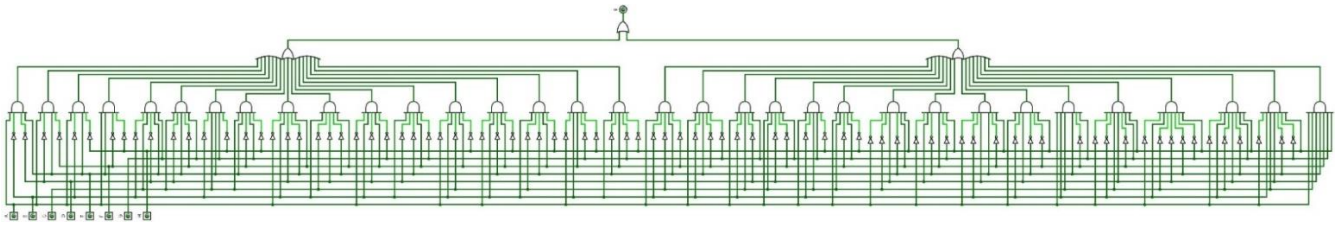

Fig. 10. Logic diagram for Output S

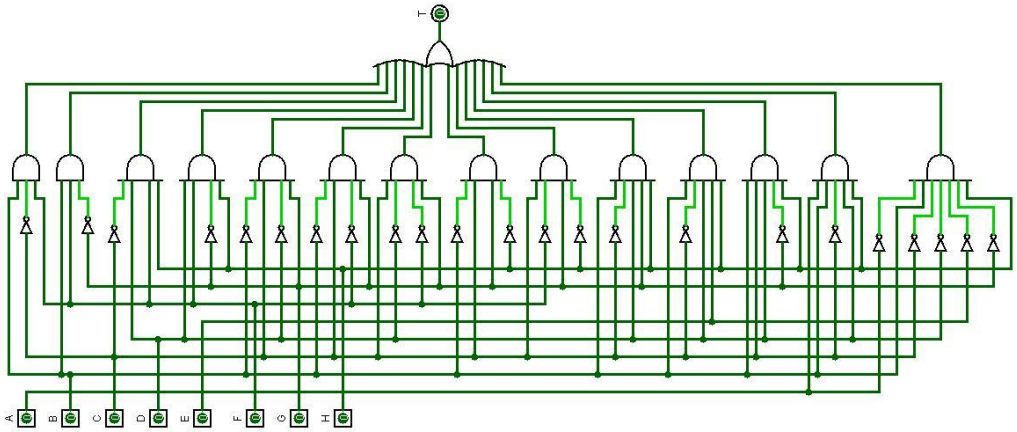

Fig. 11. Logic diagram for Output T

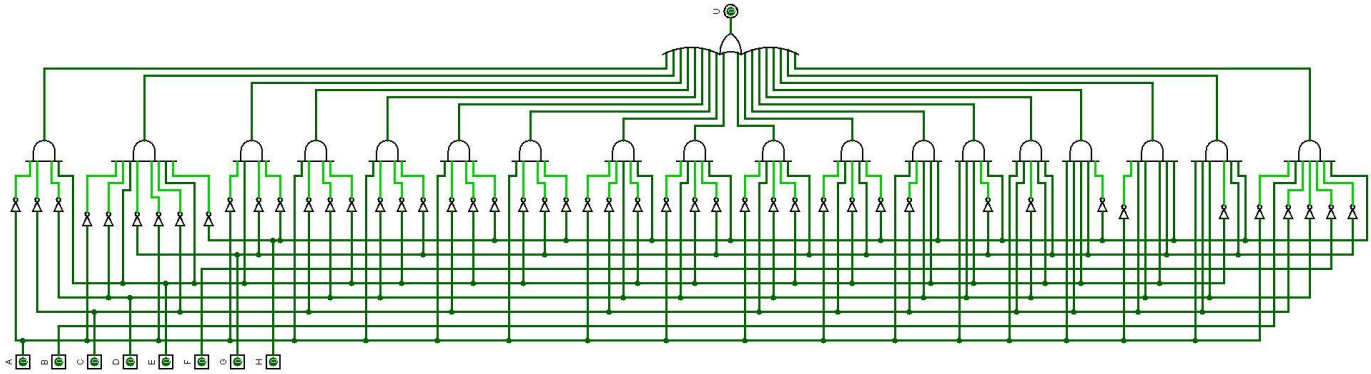

Fig. 12. Logic diagram for Output U

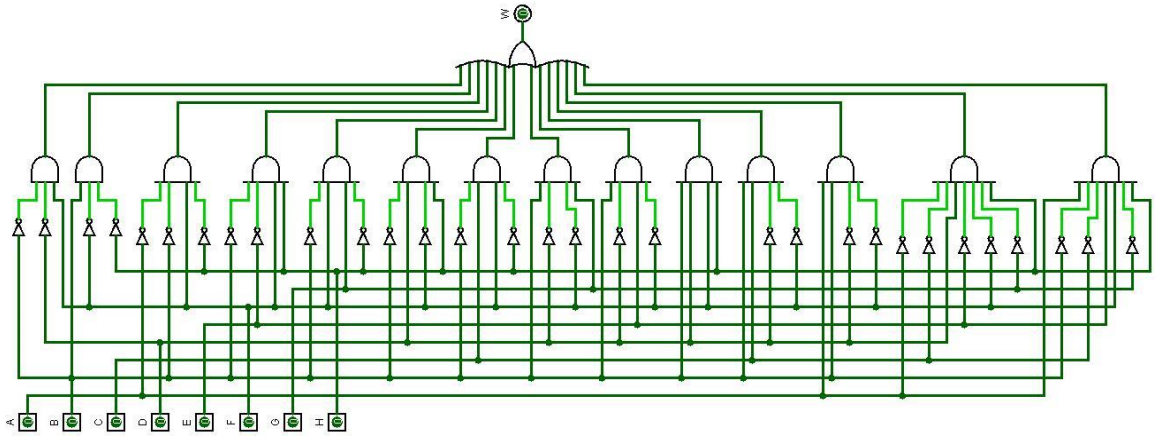

Fig. 13. Logic Diagram for Output W.

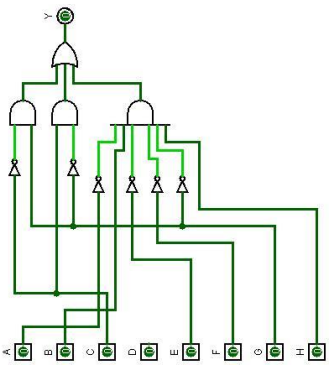

Fig. 14. Logic diagram for Output Y.

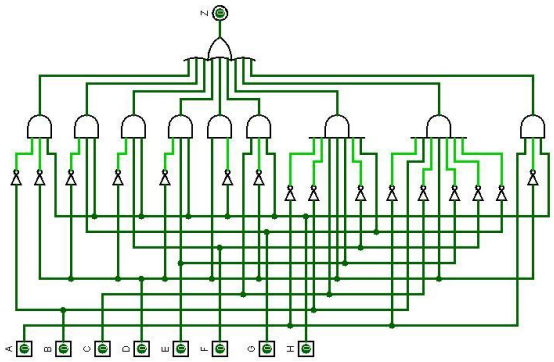

Fig. 15. Logic Diagram for Output Z.

IV. Results

Complex binary adder designs presented in the previous section have been implemented on Xilinx[9] FPGAs and various statistics pertaining to each design are given in Tables 3-5.

TABLE. III. FPGA Implementation Results of Complex Binary Ripple-Carry Adder (CBRCA) and base 2 Adder [5]

	Complex Binary Ripple-Carry Adder Implementations on FPGA Devices			Base 2 Ripple-Carry Adder Implementation
	XC 4003E	Spartan XCS05	Virtex XCV50	Virtex XCV50
Number of external IOBs[a]	20/80 (32%)	20/80 (32%)	20/94 (21%)	13/94 (13%)
Number of CLBs[b] (Slices[c])	24/100 (24%)	24/100 (24%)	31/768 (4%)	6/768 (1%)
Number of 4 input LUTs[d]	42/200 (21%)	42/200 (21%)	59/1536 (3%)	9/1536 (1%)
Number of 3 input LUTs	13/100 (13%)	13/ 100 (13%)		
Number of bonded IOBs	20/61 (32%)	20/ 61 (32%)	20/ 94 (21%)	13/94 (13%)
Gate count	310	310	354	54
Average connection delay (ns)	2.808	3.506	1.640	1.525
Maximum combinational delay (ns)	35.680	45.995	24.839	15.389

[a]IOBs: Programmable Input/Ouput Blocks.
[b]CLBs: Configurable Logic Blocks.
[c]Slice: Each Virtex CLB contains 4 logic cells organized in two similar slices.
[d]LUTs: Lookup Tables.

TABLE. IV. FPGA Implementation Results of Complex Binary Decoder-based Adder and base 2 Adder [5]

	Complex Binary Decoder-based Adder Implementation on FPGA Device	Base 2 Decoder-based Adder Implementation
	Virtex V50CS144	Virtex V50CS144
Number of external IOBs	20/94 (21%)	13/94 (13%)
Number of CLBs(Slices)	455/768 (59%)	391/768 (50%)
Number of 4 input LUTs	857/1536 (55%)	755/1536 (49%)
Number of bonded IOBs	20/94 (21%)	13/94 (13%)
Gate count	5142	4530
Average connection delay (ns)	3.179	3.169
Maximum combinational delay (ns)	32.471	28.442

TABLE. V. FPGA IMPLEMENTATION RESULTS OF COMPLEX BINARY MINIMUM-DELAY ADDER [10]

	Complex Binary Minimum-Delay Adder Implementations on FPGA Devices		
	Virtex4 XC4VLX15	Virtex5 XC5VLX30	Virtex XCV100
Number of external IOBs	20/240 (8%)	20/220 (9%)	20/180 (11%)
Number of CLBs(Slices)	27/6144 (>1%)	25/19200 (1%)	27/1200 (2%)
Number of 4 input LUTs	52/12288 (>1%)	0/27	52/2400 (2%)
Number of bonded IOBs	20/240 (6%)	20/220 (9%)	20/180 (11%)
Gate count	330	175	330
Maximum net delay (ns)	5.028	2.790	8.856
Maximum combinational delay (ns)	7.827	4.776	17.001

ACKNOWLEDGMENT

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Enhanced Mutual Authenticated Key Agreement Protocol for Anonymous Roaming Service in Global Mobility Networks

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***Abstract*—With the rapid development of mobile intelligent terminals, users can enjoy ubiquitous life in global mobility networks (GLOMONET). It is essential to secure user information for providing secure roaming service in GLOMONET. Recently, Xu et al. proposed a mutual authentication and key agreement (MAKA) protocol as the basic security building block. The purpose of this paper is not only to show some security problems in Xu et al.'s MAKA protocol and but also proposes an enhanced MAKA protocol as a remedy protocol for Xu et al.'s MAKA protocol. The proposed protocol ensures higher security compared to the well-known authentication and key agreement protocols but has a bit computational overhead than them due to the security enhancements.**

***Keywords*—Information security; roaming security; anonymity; authenticated key agreement; cryptanalysis**

I. Introduction

GLOMONET provides global roaming service to users moving from one network to another [1-2]. Users can enjoy rich and colorful services, such as online shopping, social entertainment, bank transfer and security exchange, with the help of GLOMONET network entities. Roaming service enables mobile user (MU) to use the services extended by home agent (HA) in a foreign agent (FA). Thus, user authentication and key agreement protocol for roaming service plays the very important role in GLOMONET [3-5]. In particular, the authentication and key agreement protocol for roaming service enables a MU and a FA authenticate each other and agree on a common session key to establish a secure channel over GLOMONET with the help of the HA. During roaming process in GLOMONET, privacy protection, especially focused on user anonymity, is a challenging and essential requirement that the identity of MU is protected against adversaries. Mutual authentication is also a very important security aspect. It requires that MU, FA and HA prove their authenticity to each other before offering any application services in GLOMONET.

To support roaming facility, several authentication and key agreement protocols [6-] have been proposed in GLOMONET. However, many of them have been proved to be insecure against known attacks. Zhu et al. proposed a two-factor authentication scheme but Lee et al. showed that Zhu et al.'s scheme does not achieve mutual authentication and is vulnerable to impersonation attack [6-7]. Furthermore, Lee et al. proposed a remedy scheme for Zhu et al.'s scheme. But Wu et al. showed that Lee et al.'s scheme fails to provide user anonymity [8]. Wang et al. also introduced a new authentication scheme but Jeon et al. pointed out that Wang et al.'s scheme cannot withstand against forgery attacks and fails to achieve anonymity [9-10]. Independently, Chang et al. proved Lee et al.'s scheme fails to achieve user anonymity and proposed a new authentication scheme [11]. Unfortunately, Youn et al. found that Change et al.'s scheme cannot provide anonymity [12]. Recently, Zhou et al. proposed a MAKA protocol based on the decisional Diffie–Hellman assumption [13]. While Gope et al. pointed out that Zhou et al.'s protocol is vulnerable to reply attacks and insider attack and proposed a new protocol [14]. However, Xu et al. showed that Gope et al.'s protocol is susceptible to replay attack and have a large storage burden with some more problems and proposed a new novel efficient MAKA protocol with desynchronization for anonymous roaming service in GLOMONET [15].

There are two purposes of this paper, to show deficiencies of Xu et al.'s protocol and to propose a new remedy MAKA protocol. Xu et al.'s protocol is lightweight but has a protocol flaw and is susceptible to off-line identifier and password guessing attack, stolen verifier attack and denial of service (DoS) attack. We utilize symmetric cryptosystem to implement pseudonym identifier in each session, which can achieve anonymity. Therefore, the proposed protocol could achieve more secure properties compared to the other well-known MAKA protocols but has a bit more overhead to draw some more functions to be secure enough.

The rest of the paper is organized as follows: in Section II, we provide a brief overview of GLOMONET and Xu et al.'s MAKA protocol. Section III provides an attack model and security flaws in Xu et al.'s MAKA protocol. Sections IV and V propose an enhanced MAKA protocol to solve the weaknesses in Xu et al.'s protocol with the security and performance analysis. Finally, Section VI provides the conclusion.

II. Backgrounds

This section provides an overview of the target network and Xu et al.'s MAKA protocol [15]. The purpose of this section is to withdraw security flaws in Xu et al.'s MAKA protocol.

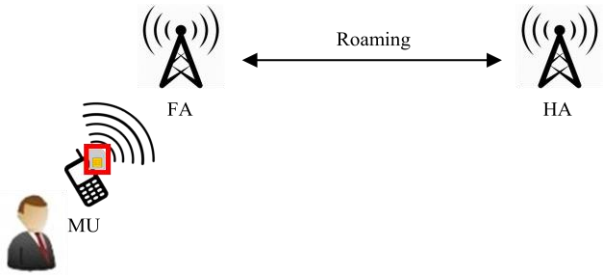

Fig. 1. Network Configuration for GLOMONET.

A. Global Mobility Network

Increased use of digital communication systems including cellular phones has led to support the roaming service in GLOMONET. Mobility is a function, which enables a MU to access the services of foreign network (FN) while roaming [16]. In GLOMONET, MUs can access their home network (HN) services from remote places with the help of FA. Authenticity of the MUs plays a crucial role to gain the access to the network services. In roaming scenario, there are three entities, MU, FA and HA. MUs in GLOMONETs visit FN, the role of FN is to authenticate MU with the help of HA as shown in Fig. 1.

B. Xu et al.'s MAKA Protocol

Xu et al. proposed a MAKA protocol as a remedy scheme of Gope et al.'s protocol [15]. This subsection reviews Xu et al.'s MAKA protocol. Table 1 shows the notations used in this paper.

Xu et al.'s MAKA protocol is consisted of four phases, registration phase, mutual authentication and key agreement phase, password renewal phase and shared key renewal phase.

[Registration phase] In this phase, MU uses real identity to register in HA through secure channel. After registration, MU gets a SC, which stores the authentication information. The details are

Step 1: MU sends his/her identity ID_M to HA through the secure channel.

Step 2: After receiving ID_M, HA randomly generates two numbers n_h and n_0 and then computes $K_{uh} = h(ID_M||n_h)$ and $EID = E_k(ID_M||n_0)$. Hereafter, HA stores ID_M and K_{uh}, forms a message $\{EID, K_{uh}, h()\}$ and sends it to MU through a secure channel.

Step 3: MU chooses a password PSW_M upon receiving the message sending from HA. And MU computes $EID^* = EID \oplus h(ID_M||PSW_M)$, $K_{uh}^* = K_{uh} \oplus h(ID_M||PSW_M)$. Finally, MU replaces EID with EID^* and K_{uh} with K_{uh}^*. Now SC contains $\{EID^*, K_{uh}^*, h()\}$.

[Message authentication and key agreement phase] In this phase, MU and FA authenticate and establish a session key each other with the assistance of HA. The details are

Step 1: MU generates a random number N_m and submits his/her identity ID_M and password PSW_M to SC. MU derives $K_{uh} = K_{uh}^* \oplus h(ID_M||PSW_M)$, $EID = EID^* \oplus h(ID_M||PSW_M)$ and computes $N_x = h(ID_M||K_{uh}) \oplus N_m$ and $V_1 = h(EID||N_x||T_1||ID_M||K_{uh})$. Finally, MU forms a message $M_{A1} : \{EID, N_x, ID_h, V_1, T_1\}$ and sends it to FA.

Step 2: After receiving M_{A1}, FA first checks whether the current time is within T_1. If not, the protocol terminates immediately. Otherwise, FA generates a random number N_f and computes $N_y = h(K_{fh}) \oplus N_f$ and $V_2 = h(EID||N_x||N_y||T_2||K_{fh}||N_f)$. Finally, FA forms a message M_{A2}: $\{EID, N_x, ID_f, V_1, T_1, N_y, V_2, T_2\}$ and sends it to HA.

Step 3: When HA receives M_{A2}, it checks whether the current time is within T_2. If not, the protocol terminates immediately. Otherwise, HA computes $N_f = h(K_{fh}) \oplus N_y$, $V_2^* = h(EID||N_x||N_y||T_2||K_{fh}||N_f)$ and then it checks whether V_2^* is equal to V_2. If not, it will terminate the connection. Otherwise, HA decrypts EID through $ID_M||n_0 = D_k(EID)$. Next, it computes $V_1^* = h(EID||N_x||T_1||ID_M||K_{uh})$ and checks whether V_1^* is equal to V_1. If not, it terminates the connection. Otherwise, HA generates a random number n_1 and computes $D = E_k(ID_M||n_1)$ and $FID^* = FID \oplus h(ID_M||K_{uh})$. Hereafter, it derives $N_m = h(ID_M||K_{uh}) \oplus N_x$, $N_x' = h(K_{uh}||ID_M||N_m) \oplus N_f \oplus n_0$, $N_y' = h(K_{fh}||ID_f||N_f) \oplus N_m \oplus n_0$, $V_3 = h(N_y'||N_f) \oplus K_{fh}$, and $V_4 = h(N_x'||FID^*||N_m) \oplus K_{uh}$. At last, HA forms a response message M_{A3}:$\{N_x', N_y', V_3, V_4, FID^*\}$ and sends it to FA.

Step 4: Upon receiving M_{A3}, FA computes $V_3^* = h(N_y'||N_f) \oplus K_{fh}$ and checks whether it is equal to V_3. If so, it derives $N_m \oplus n_0 = h(K_{fh}||ID_f||N_f) \oplus N_y'$ and computes a session key $SK = N_m \oplus n_0 \oplus N_f$. Finally, it sends the message $M_{A4} : \{N_x', V_4, FID^*\}$ to MU.

Step 5: Upon receiving M_{A4}, MU computes $V_4^* = h(N_x'||FID^*||N_m) \oplus K_{uh}$ and checks whether it is equal to V_4. If the verification is successful, he/she computes $N_f \oplus n_0 = h(K_{uh}||ID_M||N_m) \oplus N_x'$ and derives the session key $SK = N_m \oplus n_0 \oplus N_f$ and then, he/she computes $FID = FID^* \oplus h(ID_M||K_{uh})$ and replaces EID with FID.

[Password renewal phase] To change the password, MU needs to use his/her old password PSW_M and enter the new password PSW_M^*. After that, MU computes $K_{uh} = K_{uh}^* \oplus h(ID_M||PSW_M)$, $EID = EID^* \oplus h(ID_M||PSW_M)$, $K_{uh}^{**} = K_{uh} \oplus h(ID_M||PSW_M^*)$ and $EID^{**} = EID \oplus h(ID_M||PSW_M^*)$. MU replaces K_{uh}^* with K_{uh}^{**} and EID^* with EID^{**} in SC.

TABLE I. NOTATIONS

Symbol	Description
MU	Mobile user
FA	Foreign agent
HA	Home agent
SC	Smartcard
SK	Session key
ID_M	Identity of MU
ID_h	Identity of HA
ID_f	Identity of FA
PWS_M	Password of MU
K_{uh}	Shared key between MU and HA
K_{fh}	Shared key between FA and HA
r_i, N_i	Random numbers
T_i	Timestamp
$E_k(.)$, $D_k(.)$	Symmetric key encryption/decryption with key k
EID	Dynamic identity of MU
$h(.)$	One-way hash function
$\|\|$	Bitwise concatenation
$\oplus$	Bitwise exclusive-or

[Shared key renewal phase] This phase is to reestablish the shared key between MU and HA after the shared key is suspected of disclosure. Firstly, MU sends his/her real identity ID_M to HA through secure channel and HA computes the new shared key $K_{uh} = K_{uh}^{*} \oplus h(ID_M || n_h)$ and sends it to MU through the secure channel. After receiving the message, MU updates the shared key in SC.

III. Cryptanalysis on Xu et al.'s MAKA Protocol

This section provides cryptanalysis on Xu et al.'s MAKA protocol based on Dolev-Yao security model in [17]. We will show that Xu et al.'s MAKA protocol is weak against off-line identifier and password guessing attack, stolen verifier attack and denial of service attack with a protocol flaw.

A. Dolev-Yao Attack Model

The motivation of Dolev-Yao model is to verify public key protocols against active attacks with considerable power [17]. In their model, following attacker assumptions are

- Adversary has complete control over the entire network
- Adversary acts as a legitimate user and can obtain any message from any party
- Adversary can initiate the protocol with any party and can be a receiver to any party in the network.

Furthermore, we add two more assumptions to Dolev-Yao model that are for the proper cryptanalysis of MAKA protocol as follows

- Adversary may obtain all the sensitive parameters stored in SC's by monitoring the power consumption of it if adversary could steal MU's SC [18]
- Adversary can steal the verification table from HA.

B. Security Weakness in Xu et al.'s MAKA Protocol

This section shows the security weaknesses of Xu et al.'s MAKA protocol, which will shows that adversary can mount different types of attacks on the MAKA protocol based on Dolev-Yao attack model with two additional assumptions described in the subsection 3.1. Firstly, we will show a flaw in Xu et al.'s MAKA protocol and will show three security weaknesses in it.

[Protocol Flaw] A security protocol is a concrete protocol that performs a security related function and applies cryptographic methods. It should be a sufficiently detailed protocol, which can be used to implement multiple and interoperable versions of a program [19]. However, Xu et al.'s MAKA protocol is incomplete because it does not define *FID* properly but just used to form FID^{*} in step 3 of the message authentication and key agreement phase. That is the reason why we would like to change *D* into *FID* for the proper protocol run.

[Off-Line Identifier and Password Guessing Attack] Since the message authentication and key agreement phase of Xu et al.'s MAKA protocol is executed in the open network environment, an attacker can eavesdrop the communication channels among MU, FA and HA before the start of this attack. Moreover, we assumed that the attacker stole MU's SC. Thus, the attacker could get the messages, M_{A1} : {*EID*, N_x, ID_h, V_1, T_1}, M_{A2} : {*EID*, N_x, ID_f, V_1, T_1, N_y, V_2, T_2}, M_{A3} : {N_x', N_y', V_3, V_4, FID^{*}} and M_{A4} : {N_x', V_4, FID^{*}} from the communication channels. Furthermore, the attacker could get the important information on the memory of SC of MU, {EID^{*}, K_{uh}^{*}, *h*()}. By using the acquired information, the attacker could compute $EID \oplus K_{uh} = EID^{*} \oplus K_{uh}^{*}$ from the memory of SC and get $K_{uh}' = EID \oplus K_{uh} \oplus EID$ by using *EID* in M_{A1}. After that, the attacker could perform the off-line identifier and password guessing attack as follows. First of all, the attacker tries to perform the identifier guessing attack by using V_1 with the related information. (1) The attacker guesses an identifier candidate ID_{Mi} and computes $V_1' = h(EID || N_x || T_1 || ID_{Mi} || K_{uh}')$ in an off-line manner. (2) The attacker checks whether V_1' is equal to V_1 or not. If they are the same, the identifier guessing is successful. Otherwise, the attacker repeats Steps (1) and (2) until the correct one is withdrawn. After that with the properly derived ID_{Mi}, the attacker tries the password guessing attack by using EID^{*} or K_{uh}^{*} with the related information. (1) The attacker guesses a password candidate PSW_{Mi} and computes $EID^{*'} = EID \oplus h(ID_{Mi} || PSW_{Mi})$ in an off-line manner. (2) The attacker checks whether $EID^{*'}$ is equal to EID^{*} or not. If they are the same, the password guessing is successful. Otherwise, the attacker repeats Steps (1) and (2) until the correct password is withdrawn.

[Stolen Verifier Attack] The legitimacy of user in Xu et al.'s MAKA protocol is determined based on the verifier. As we mentioned in the attack model, an attacker can steal the verifier {ID_M and K_{uh}} stored in HA for this attack. Even if the verifier does not include the secret key of HA, the attacker could pretend to be an honest HA for MU by forming a legitimate message M_{A4}, which needs to be send to MU. The attacker could perform the FA masquerading attack based on the stolen verifier attack as follows. (1) The attacker performs a dictionary attack to find the proper identifier ID_{Mi} by using $V_1' = h(EID || N_x || T_1 || ID_{Mi} || K_{uh}')$ based on the verifier with the request message M_{A1}: {*EID*, N_x, ID_h, V_1, T_1} from MU in an off-line manner. (2) The attacker forms a legal message M_{A4} : {N_x', V_4, FID^{*}} after selecting two random numbers N_x' and FID^{*}, deriving $N_m' = N_x \oplus h(ID_{Mi} || K_{uh})$ and computing $V_4 = h(N_x' || FID^{*} || N_m') \oplus K_{uh}$. (3) The attacker derives a session key as $SK = N_m' \oplus h(K_{uh} || ID_{Mi} || N_m') \oplus N_x'$, which will be the same with MU's computation.

[Denial of Service Attack] This attack is a cyber-attack in which the perpetrator seeks to make a resource unavailable to its intended users by disrupting services of a host. The password renewal phase only changes without checking the ownership of MU. That is the reason why any attacker could try to perform that phase with any PSW_{Mi} and PSW_{Mi}^{*} pair when MU temporarily vacate his/her system with SC. The attacker performs denial of service attack as follows. (1) The attacker uses two random numbers for passwords PSW_{Mi} and PSW_{Mi}^{*}. (2) The attacker computes $K_{uh}' = K_{uh}^{*} \oplus h(PSW_{Mi})$, $EID' = EID^{*} \oplus h(PSW_{Mi})$, $K_{uh}'' = K_{uh}' \oplus h(PSW_{Mi}^{*})$ and $EID'' = EID' \oplus h(PSW_{Mi}^{*})$. (3) The attacker replaces K_{uh}^{*} with K_{uh}^{**} and EID' with EID'' in SC. After this, MU cannot use the service from FA based on SC.

IV. Enhanced MAKA Protocol

This section proposes an enhanced MAKA protocol to overcome the weaknesses of Xu et al.'s MAKA protocol. We need to design a new protocol, which does not use verification table in HA side with the other aspects to resist various attacks. The design goals of our enhanced MAKA protocol are as follows

- To achieve mutual authentication with the provision of anonymity
- To establish the session key fairly
- To resist common attacks, such as guessing attack, lost smart card attack, denial of service attack and so on
- To provide user friendliness of password change
- To achieve computational and communicational efficiency.

Enhanced MAKA protocol is composed of three phases, registration phase, mutual authenticated key agreement phase and password renewal phase. Enhanced MAKA protocol does not need to have the shared key renewal phase because the key is updated once in the mutual authenticated key agreement phase run. In the registration phase, MU registers any specific services to HA by using real identity through secure channel. Unlike Xu et al.'s MAKA protocol, enhanced MAKA protocol does not need to use a verifier table in HA, which improves the security of the protocol. The mutual authenticated key agreement phase provides mutual authentication and key agreement. In this phase, MU and FA can authenticate each other with the assistance of HA with a proper session key establishment. The password renewal allows MU to update the password without the supervision of HA only after the proper MU authentication.

A. Registration Phase

In this phase, MU registers his/her identity to HA and HA issues MU a SC to be used in the further phases. The whole processes of this phase require to be processed through a secure channel. Fig. 2 depicts the processes of this phase, which are given in detail as follows

Step 1: MU selects and sends his/her real identity ID_M to HA.

Step 2: After receiving ID_M, HA generates a random number n_0 and computes $K_{uh} = h(ID_M||n_0)$ and $EID = E_k(ID_M||n_0)$, which k is the master key only known by HA and EID is the dynamic identity of MU. HA issues a SC by writing $\{EID, K_{uh}, h()\}$ in the memory of it and sends it to MU.

Step 3: MU chooses a password PSW_M upon receiving the message sending from HA. MU computes $EID^* = EID \oplus h(ID_M||PSW_M)$, $K_{uh}^* = K_{uh} \oplus h(PSW_M||ID_M)$ and $AV = h(EID||K_{uh})$. Finally, MU replaces EID with EID^* and K_{uh} with K_{uh}^*. Now SC contains $\{EID^*, K_{uh}^*, AV, h()\}$.

The important feature in this phase is that it does not need to keep ID_M and n_0 in HA side for the further processing of the protocol, which could enhance the security of the protocol.

B. Mutual Authenticated Key Agreement Phase

In this phase, MU and FA can establish a session key only after mutual authentication is successful with the assistance of HA. It uses the dynamic identity to achieve anonymity of MU. Fig. 3 depicts the processes of this phase, which are given in detail as follows

Step 1: MU inputs ID_M and PSW_M to SC. SC derives $K_{uh} = K_{uh}^* \oplus h(PSW_M||ID_M)$ and $EID = EID^* \oplus h(ID_M||PSW_M)$ and computes $AV' = h(EID||K_{uh})$. If AV' is not equal to AV, SC terminates the protocol. Otherwise, SC generates a random number N_m and computes $N_x = h(ID_M||K_{uh}) \oplus N_m$ and $V_1 = h(EID||N_x||T_1||ID_M||K_{uh})$. Finally, SC forms M_{A1} : { EID, N_x, ID_h, V_1, T_1} where T_1 is a timestamp of SC and sends it to FA.

Step 2: After receiving M_{A1}, FA first checks whether the current time is within T_1. If not, the protocol terminates immediately. Otherwise, FA generates a random number N_f and computes $N_y = h(K_{fh}) \oplus N_f$ and $V_2 = h(EID||N_x||N_y||T_2||K_{fh}||N_f)$. After that, FA forms M_{A2} : { EID, N_x, ID_f, V_1, T_1, N_y, V_2, T_2} where T_2 is a timestamp of FA and sends it to HA.

Step 3: When HA receives M_{A2}, it checks if the current time is within T_2. If not, the protocol terminates immediately. Otherwise, HA computes $N_f = h(K_{fh}) \oplus N_y$, $V_2^* = h(EID||N_x||N_y||T_2||K_{fh}||N_f)$ and then it checks if V_2^* is equal to V_2. If not, it terminates the connection. Otherwise, HA decrypts EID through $ID_M||n_0 = D_k(EID)$ and computes $K_{uh}' = h(ID_M||n_0)$. After that, it computes $V_1^* = h(EID||N_x||T_1||ID_M||K_{uh}')$ and checks if V_1^* is equal to V_1. If not, it terminates the connection. Otherwise, HA generates a random number n_1 and computes $FID = E_k(ID_M||n_1)$, $FID^* = FID \oplus h(ID_M||K_{uh}')$ and $K_{uh}^{**} = h(ID_M||n_1) \oplus h(ID_M||K_{uh}'||N_m)$. After that, it derives $N_m = h(ID_M||K_{uh}) \oplus N_x$, $N_x' = h(K_{uh}||ID_M||N_m) \oplus N_f \oplus n_0$, $N_y' = h(K_{fh}||ID_f||N_f) \oplus N_m \oplus n_0$, $V_3 = h(N_y'||N_f||T_3) \oplus K_{fh}$, and $V_4 = h(N_x'||FID^*||K_{uh}^{**}||N_m||T_3) \oplus K_{uh}'$. At last, HA forms a response message M_{A3} : { N_x', N_y', V_3, V_4, FID^*, K_{uh}^{**}, T_3 } where T_3 is a timestamp of FA and sends it to FA.

Step 4: Upon receiving M_{A3}, FA checks whether the current time is within T_3. If not, the protocol terminates immediately. Otherwise, FA computes $V_3^* = h(N_y'||N_f||T_3) \oplus K_{fh}$ and checks whether it is equal to V_3. If so, it derives $N_m \oplus n_0 = h(K_{fh}||ID_f||N_f) \oplus N_y'$ and computes the session key $SK = N_m \oplus n_0 \oplus N_f$. Finally, it sends the message M_{A4} : { N_x', V_4, FID^*, K_{uh}^{**}, T_3 } to MU.

Step 5: Upon receiving M_{A4}, SC checks whether the current time is within T_3. If not, the protocol terminates immediately. Otherwise, SC computes $V_4^* = h(N_x||FID^*||K_{uh}^{**}||N_m||T_3) \oplus K_{uh}$ and checks whether it is equal to V_4. If the verification is successful, SC computes $N_f \oplus n_0 = h(K_{uh}||ID_M||N_m) \oplus N_x'$, derives the session key $SK = N_m \oplus n_0 \oplus N_f$. After that, SC computes $FID' = FID^* \oplus h(ID_M||K_{uh})$ and $K_{uh}'' = K_{uh}^{**} \oplus h(ID_M||K_{uh}||N_m)$, and updates $EID^* = FID' \oplus h(ID_M||PSW_M)$, $K_{uh}^* = K_{uh}'' \oplus h(PSW_M||ID_M)$ and $AV = h(EID'||K_{uh}'')$ on it.

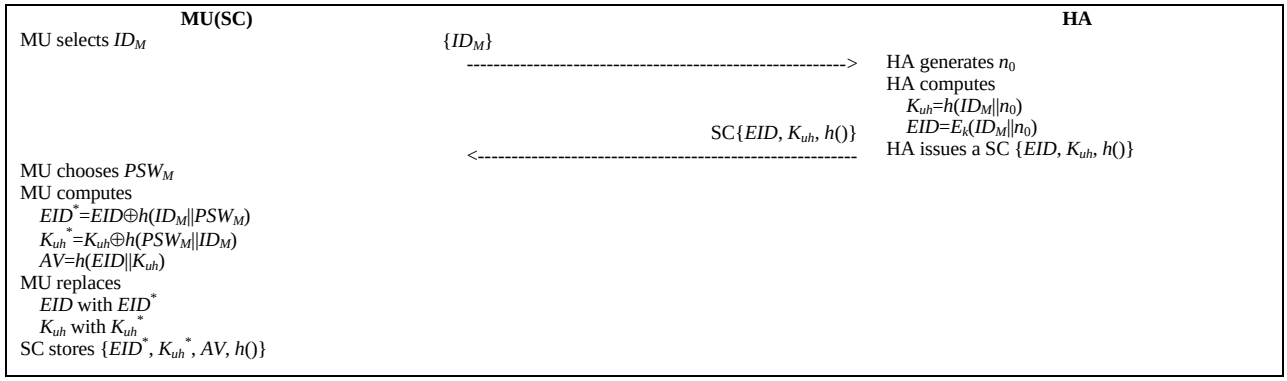

Fig. 2. The Registration Phase of Enhanced MAKA Protocol.

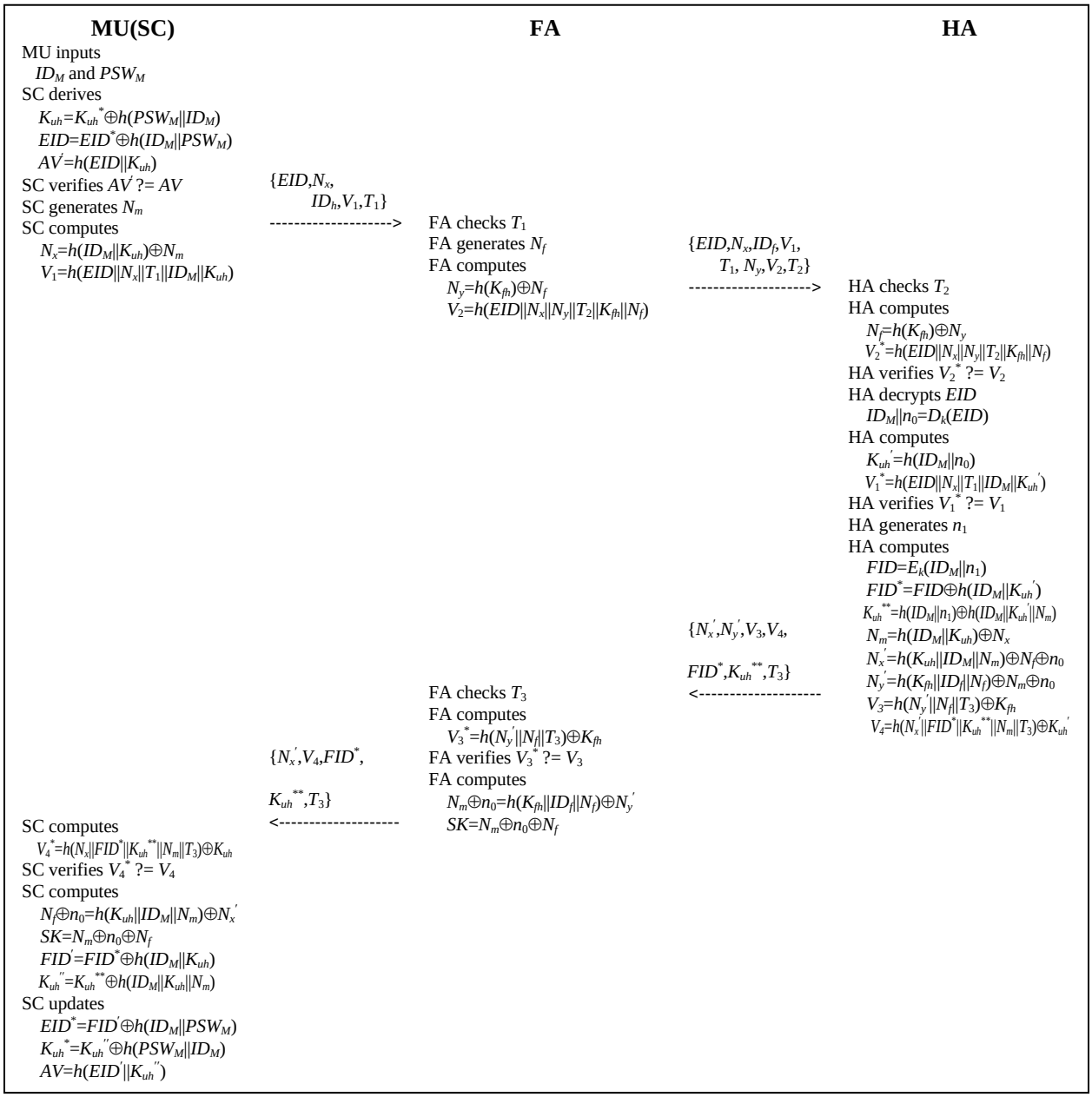

Fig. 3. The Mutual Authenticated Key Agreement Phase of Enhanced MAKA Protocol.

This phase regularly updates MU's dynamic identity and secret key between MU and HA. These features could enhance anonymity of user and security of the protocol.

C. Password Renewal Phase

MU can change his/her password without the supervision of HA. To change the password, MU needs to pass the ownership of SC first. For this, MU inputs ID_M and PSW_M to SC. SC derives $K_{uh} = K_{uh}^* \oplus h(PSW_M||ID_M)$ and $EID = EID^* \oplus h(ID_M||PSW_M)$ and computes $AV' = h(EID||K_{uh})$. If AV' is not equal to AV, SC terminates the protocol. Otherwise, SC asks MU to input a new password PSW_M^*. SC updates $EID^* = EID \oplus h(ID_M||PSW_M^*)$ and $K_{uh}^* = K_{uh} \oplus h(PSW_M^*||ID_M)$ on it.

V. Analysis

This section provides analysis of security and performance of enhanced MAKA protocol by comparing it with Gope et al.'s protocol in [14] and Xu et al.'s MAKA protocol in [15].

A. Security Analysis

The security analysis is performed based on the Dolev-Yao model with two more assumptions as described in Section 3.1. We solved the issues in Xu et al.'s MAKA protocol mentioned in Section 3.2. Unlike Xu et al.'s MAKA protocol and Gope et al.'s protocol, the proposed protocol does not need to consider the stolen verifier attack. Thereby, as shown in Table 2, the proposed enhanced MAKA protocol provides more secure and efficient properties.

[Providing Mutual Authentication] Enhanced MAKA protocol uses Challenge-Response mechanism together with timestamp. The goal of enhanced MAKA protocol is to provide mutual authentication between MU and FA. However, FA does not have direct way to authenticate MU that is the reason why it should depend on HA, which has credential relationship with MU. HA authenticates MU through V_1 by checking the possession of the correct pair of ID_M and K_{uh} and FA based on V_2 for the correctness of K_{fh}. Only the attacker with the knowledge of ID_M and K_{uh} could masquerade as a legal MU and the same for FA with K_{fh}. Furthermore, MU also authenticates FA by helping of HA based on V_4. Only the legal FA could pass the correct V_4 via HA. Addition to this, FA authenticates HA based on V_3, which only the correct HA could form it by using K_{fh}. Therefore, through the help of HA, MU and FA perform the mutual authentication since an attacker from the attack model could not do anything to masquerade any party in the proposed protocol.

TABLE II. Security Properties between Protocols

Protocol	UA[a]	MA[b]	PGA[c]	PVA[d]	PDA[e]
Gope et al.	Provide	Provide	No	No	No
Xu et al.	Provide	Provide	No	No	No
Proposed	Provide	Provide	Yes	Yes	Yes

[a.] UA: User Anonymity, [b.] MA: Mutual Authentication, [c.] PGA: Provision of Guessing Attack
[d.] PVA: Prevention of Verifier Attack, [e.] PDA: Provision of DoS Attack

[Providing Key Agreement] A fair key agreement protocol is a protocol that the session key contains the contribution of each participant. In our enhanced MAKA protocol, the session key is derived based on MU and FA's session dependent random numbers N_m and N_f together with n_0, which satisfies the fair session key agreement. MU and FA perform the key agreement via HA securely since an attacker from the attack model could not do anything to know the session key in the proposed protocol.

[Providing Anonymity of User] Since wireless network is more vulnerable to several attacks and mobile terminals' computational power is limited, anonymity in protocol design is an important issue. Anonymity is the ability of an individual to seclude himself/herself or information about himself/herself. Enhanced MAKA protocol uses pseudonym, EID, for this purpose. Furthermore, the pseudonym is dynamically chanced in each session to provide anonymity. An attacker from the attack model could not do anything to know the identity of MU in the proposed protocol.

[Prevention of Off-line Identifier and Password Guessing Attack] An attacker could get the messages, M_{A1} : $\{EID, N_x, ID_h, V_1, T_1\}$, M_{A2} : $\{EID, N_x, ID_f, V_1, T_1, N_y, V_2, T_2\}$, M_{A3} : $\{N_x', N_y', V_3, V_4, FID^*, K_{uh}^{**}, T_3\}$ and M_{A4} : $\{N_x', V_4, FID^*, K_{uh}^{**}, T_3\}$ from the communication channels. Furthermore, the attacker could get the important information on the memory of SC of MU, $\{EID^*, K_{uh}^*, AV, h()\}$. To perform the attack, the attacker needs to know ID_M and PSW_M at the same time. However, it is infeasible to the attacker due to the lack of knowledge on k or K_{uh}. Furthermore, MU's pseudonym is updated in each session. Thereby, enhanced MAKA protocol could cope from the identifier and password guessing attack even with the assumption of the usage of non-tamper resistant smart card.

[Prevention of Denial of Service Attack] The password renewal phase of enhanced MAKA protocol provides authenticity check of MU. That is the reason why an attacker with the attack model could not do anything for the denial of service attack. Only after the success of the ownership check, MU could change his/her password with a new one and update related information on SM securely. Thereby, enhanced MAKA protocol could cope from the denial of service attack.

[Prevention of Replay Attack] Enhanced MAKA protocol uses timestamp mechanism together with challenge-response mechanism to prevent replay attacks. Timestamps and random numbers could present the freshness of messages. If the current time exceeds the permitted time threshold of the received message, the message is not fresh and it means that the attacker fakes and replays it. Under this circumstance, the protocol is finished immediately. Even if the attacker could forge a valid timestamp T_i, he/she does not have the ability to forge the related V_i, which provides the integrity of message. Thereby, enhanced MAKA protocol could cope from various replay attacks.

B. Perormance Analysis

This section discusses the performance analysis by considering operational cost of the related protocols. The computational analysis of an authentication and key agreement

protocol is generally conducted by focusing on operations performed by each party within the protocols. Therefore, for analysis of the computational costs, we concentrated on the operations that are conducted by the parties in the network: namely MU, HA and FA. In order to facilitate the analysis of the computational costs, we define the following notation.

- T_h: the time to execute a one-way hashing operation
- T_x: the time to execute an XOR operation
- T_s: the time to compute a symmetric key cryptosystem operation

In addition, in order to achieve accurate measurement, we performed an experiment. This experiment was performed using the Crypto++ Library [20] on a system using the 64-bits Windows 7 operating system, 3.2 GHz processor, 4 GB memory, Visual C++ 2013 Software, the SHA-1 hash function and the AES symmetric encryption/decryption function. We summarize the results as shown in Table 3.

TABLE III. COMPUTATIONAL OVERHEAD BETWEEN PROTOCOLS

Protocol	**MU**	**FA**	**HA**	**Total**
Gope et al.	$7T_h+6T_x$	$5T_h+4T_x$	$11T_h+7T_x$	$23T_h+17T_x$
Xu et al.	$6T_h+8T_x$	$4T_h+5T_x$	$8T_h+6T_x$ $+2T_s$	$18T_h+17T_x$ $+2T_s$
Proposed	$12T_h+11T_x$	$4T_h+5T_x$	$11T_h+9T_x$ $+2T_s$	$28T_h+25T_x$ $+2T_s$

From Table 3, we could know that the proposed enhanced MAKA protocol has a bit more overheads than the other two protocols. It is mainly due to provide ownership check for SC, remove the verification table for HA and renewal of the dynamic identity to MAKA, which are the security costs.

VI. CONCLUSION

In this paper, we proposed an enhanced MAKA protocol in GLOMONET after showing the security problems in Xu et al.'s MAKA protocol. First of all, we showed a protocol flaw and three security weaknesses in Xu et al.'s protocol. The proposed enhanced MAKA protocol solved the problems in Xu et al.'s protocol efficiently by adopting ownership check, removing the verification table and renewing the dynamic identity periodically as shown in Table 2. However, it gets a bit of overhead due to the security provision functionalities as shown in Table 3.

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Thermal Pain Level Estimation Method with Heart Rate and Cerebral Blood Flow

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***Abstract*—Method for thermal pain level estimation with heart rate and cerebral blood flow using SVM is proposed. Through experiments, it is found that thermal pain level is much sensitive to the cerebral blood flow rather than heart rate. Also, it is found that the performance of thermal pain estimation is much better than the previously proposed method with the number of blinks, the enlarging rate of pupil size.**

***Keywords*—Thermal pain; support vector machine; thermal stimulus; classification; cerebral blood flow; heart rate**

I. Introduction

A bedridden person, a person who has become a plant state, a person who cannot speak words well. Such people are difficult to convey their feelings. Therefore, there is a strong demand to create methods and systems which allows pain level prediction and representation for disable persons. Life and stress cause blood flow deterioration. In menopausal age, stress and other hormonal disturbances, capillary blood flow is not the movement of most capillaries itself, but blood flow is determined by the expansion of blood vessels called "arterioles" that lead to capillaries. Stress and autonomic nerves are very closely related. The autonomic nerve is one of the peripheral nerves and is a narrow neural network stretched to every corner of the body. It is divided into two, sympathetic and parasympathetic, and extends to all visceral organs such as blood vessels, heart, lungs and intestines. The blood flow in our brain is controlled by various regulatory functions. The typical ones are the carbon dioxide-mediated chemical regulation function in blood and the regulation function by the action of the autonomic nervous system around blood vessels in the brain.

Previously, a method for thermal pain level prediction with human eye motions, in particular, with the number of blinks and the pupil size change rate using SVM is proposed [1]. There are previously proposed methods which use pupil size [2]. It, however, is found that thermal pain level is much sensitive to pupil size change rate than pupil size itself [1]. Such this sensitivity analysis and comparative study is conducted. One of the biggest problems of the previous method is poor accuracy of thermal pain level prediction. It is still not good enough for practical use of the thermal pain level estimation. In order to overcome this situation, a new method with cerebral blood flow and heart rate which are measured by Near Infrared: NIR sensor is proposed here. In particular, thermal pain level measurement with cerebral blood flow is original idea in this study area. Also, it is found that cerebral blood flow is effective to estimate thermal pain level.

The next section describes related research works and the proposed method for prediction of thermal pain level followed by experimental method and results. Then, the results are discussed followed by conclusion. Finally, future research work is described.

II. Method for Thermal Pain Prediction with Cerebral Blood Flow and Heart Rate based on SVM

A. Related Research Works

There are not so small number of methods of thermal pain level prediction such as MEG, MRI, fMRI, EOG, EEG, etc. For instance, Pradkij Panavaranan ; Yodchanan Wongsawat proposed EEG-based pain estimation via fuzzy logic and polynomial kernel support vector machine [3]. They said that the results of pain estimation via fuzzy logic can be roughly indicate the pain state of EEG. The polynomial kernel support vector machine classifier for pain classification has high accuracy.

Also, Ruth Defrin Avi Ohry Nava Blumen Gideon Urca discussed sensory determinants of thermal pain [4].They said that both noxious heat and cold elicited a sensation of heat pain. No consistent pattern of heat-elicited pain was observed in areas in which only cold sensation was intact. Also their data suggest that the integrity of non-noxious thermal systems is essential for the normal perception of thermal pain, and that the subjective sensation of pain depends on the integration of information from nociceptive and non-nociceptive channels.

Furthermore, Raul Fernandez Rojas, Xu Huang & Keng-Liang Ou proposed a machine learning approach for the identification of a biomarker of human pain using fNIRS [5]. They said that feature extraction was completed in three different domains (time, frequency, and wavelet), and a total of 69 features were obtained. Feature selection was carried out according to three criteria, information gain (IG), joint mutual information (JMI), and Chi-squared ($\chi 2$). The significance of each feature ranking was evaluated using three learning models separately, linear discriminant analysis (LDA), the K-nearest neighbor (K-NN) and support vector machines (SVM) using the linear and Gaussian and polynomial kernels. The results showed that the Gaussian SVM presented the highest accuracy (94.17%) using only 25 features to identify the four types of pain in our database. In addition, we propose the use of the top 13 features according to the JMI criteria, which exhibited an accuracy of 89.44%, as promising biomarker of pain. This study contributes to the idea of developing an objective assessment of pain and proposes a potential biomarker of human pain using fNIRS.

James C. Eisenach, Regina Curry, Carol A. Aschenbrenner, Robert C. Coghill Timothy, T.Houle investigated pupil responses and pain ratings to heat stimuli in particular, for a reliability and effects of expectations and a conditioning pain stimulus [6]. These, however, are not so easy to measure and prediction of thermal pain due to the fact that it is difficult to recognize thermal pain with measured data and also it does cost for the measuring instruments. Also, these are not accurate enough (around 75 % of accuracy with some time delay) [6].

Pupillary responses to thermal pain stimulation in healthy volunteers (Lauren A. Banker)[1]. Pupil responses and pain ratings to heat stimuli: Reliability and effects of expectations and a conditioning pain stimulus (James C. Eisenach et al.) [6]. Although these studies are based on only the pupillary response, in this research I add elements of other eye motion.

Justin E. Brown, Neil Chatterjee, Jarred Younger, Sean Mackey investigated a physiology-based measure of pain: patterns of human brain activity distinguish painful from non-painful thermal stimulation [7]. Although this study is a study of brain activity by fMRI data using classification method of Support Vector Machine: SVM, this research is a study using eye motion data using SVM.

B. Previous System Configuration

Near Infrared: NIR camera which is mounted on a glass is used for acquisition of eye images. Fig. 1 shows the outlook and schematic view of the previously proposed system.

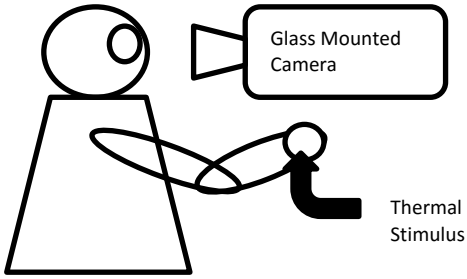
NIR camera imagery data is acquired through USB interface to PC. The outlook of the camera is shown in Fig. 2 while major specification of the camera is shown in Table I.

The experiment we conducted this time was HOT 121B developed by Hitachi. Heat stimulation is intended to be measured using the Near Infrared Sensor: NIRS which is primarily measures brain activity. The cerebral blood flow and heart rate or pulse can be measured when given and examine the change. Outlook of the HOT 121B is shown in Fig. 4 while close-up photo of the NIRS sensors are shown in Fig. 5, respectively. The cerebral blood volume of the prefrontal cortex in Alzheimer type dementia patients and healthy elderly people is measured using the near-infrared light measurement device (HOT121B), the data is corrected, and the corrected data and The data was compared and examined to clarify the difference between the two.

C. Proposed System Configuration

The system configuration of the proposed thermal pain estimation system is shown in Fig. 3.

Meanwhile, the heat source (thermal stimulus) is shown in Fig. 6. In addition, based on the data obtained by measurement, identification of measurement results was also performed using SVM (support vector machine)[2]. SVM is well known classification method which allows classify the data into the previously designated class categories. In the proposed method, two class categories, pain and not pain are designated. By using the feature components, SVM based classification is applied.



(a)Schematic view of the previous system

(b)Outlook

Fig. 1. Outlook and Schematic View of the Previously Proposed System Configuration.

Fig. 2. Outlook of the NIR Camera used.

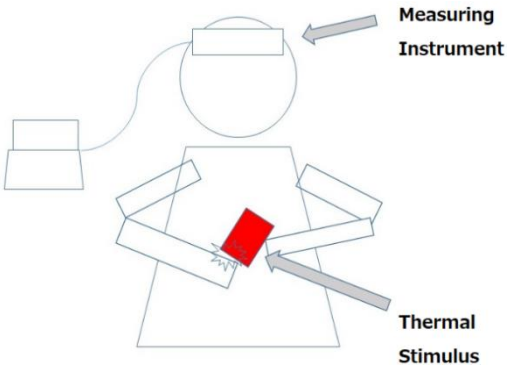


Fig. 3. System Configuration of the Proposed Thermal Pain Estimation System with NIRS Sensors.

TABLE. I. MAJOR SPECIFICATION OF THE NIR CAMERA USED

weight	200 g
Size(dimension)	21.8 x 14.8 x 7.6 cm
Camera Name	DC-NCR13U

[1]https://steinhardt.nyu.edu/appsych/psych_cafe
[2]http://opencv.jp/sample/svm.html

Fig. 4. Outlook of the HOT 121B.

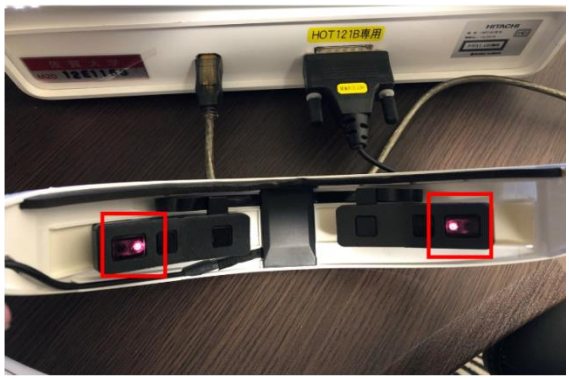


Fig. 5. Close-up Photo of the NIRS Sensors of the HOT 121B.

Fig. 6. Outlook of the Thermal Stimulus.

III. Experiments

A. Experimental Configuration

A heat-retaining bottle was covered with a wrap, and a rubber band was attached, and hot water was put in it to secure a heat source. Start the measurement with the cerebral blood flow measurement device, repeat the action of putting the heat source on the palm 10 seconds for 60 seconds and repeating the measurement three times for 210 seconds and prepare two kinds of temperature of 42 degrees and 53 degrees, and experiment went through as shown in Fig. 7.

Example of the acquired data of cerebral blood (left and right), heart rate (left and right), LF/HF (left and right) and thermal stress (Temp.) is shown in Fig. 8(a) and (b). The HF and LF of autonomic nervous function activity as stress indicators are as follows. HF is an abbreviation for High Frequency and is a fluctuating wave that uses respiration with a period of 3 to 4 seconds as a signal source. Or it is the sum of the power spectrum of the frequency domain. Also, LF is a component of lower frequency than that. HF, LF components and points to be noted when used HF components are generally calculated as the sum of power spectrum components of 0.15 to 0.40 Hz, and LF components are generally calculated as the sum of power spectrum components of 0.04 to 0.15 Hz. is there.

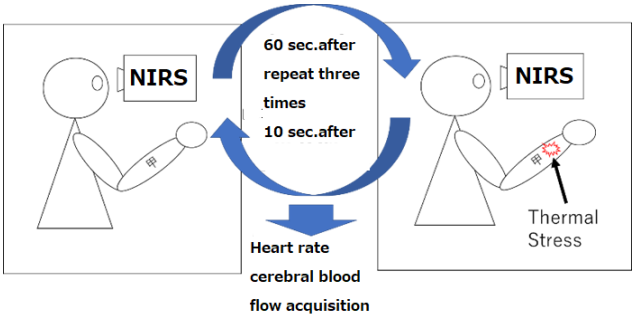
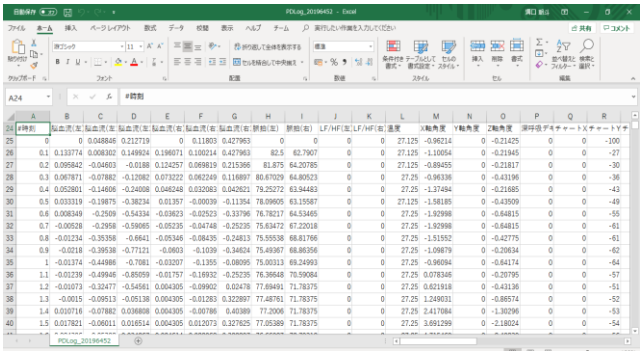
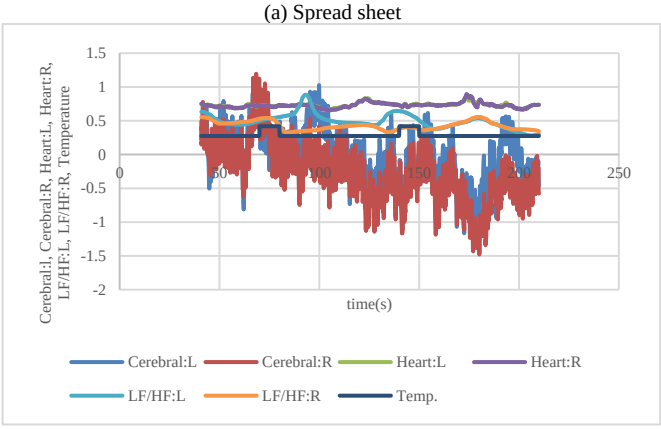


Fig. 7. Experimental Procedure.



(a) Spread sheet



(b) Graph

Fig. 8. Example of the Acquired Data of Cerebral Blood (Left and Right), Heart rate (Left and Right), LF/HF (Left and Right) and Thermal Stress (Temp).

The values divided by the sympathetic nerve (LF) and parasympathetic nerve (HF) figures do not always match the figures indicated by the balance (LF / HF). It is necessary to take into account the strength of the autonomic nervous system (the age of the autonomic nervous system) and the like as a view of the autonomic nervous system evaluation (overall evaluation).

The acquired LF/HF data means the frequency component ratio between low frequency and high frequency components of cerebral blood flow. These data are closely related psychological status between Parasympathetic nervous system and Sympathetic. Although it is useful for thermal stress detection, just cerebral blood flow and heart rate are focused in this study.

B. *Experimental Results*

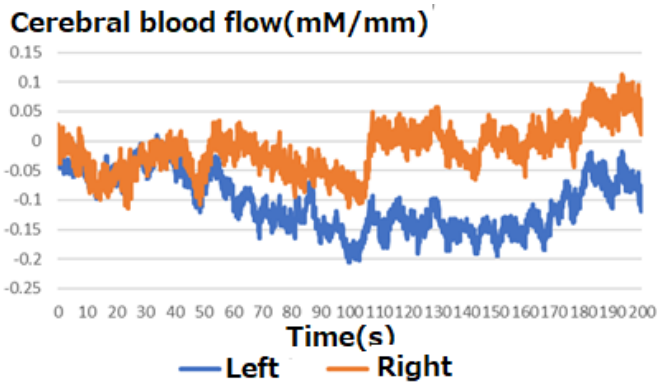
Fig. 9(a) shows the acquired time series of the cerebral blood flow for the thermal stimulus of 42 degree C while Fig. 9(b) shows that for 53 degree C, respectively. Meanwhile, Fig. 9(c) shows the acquired time series of the heart rate for 42 degree C of the thermal stimulus wile Fig. 9(d) shows that for 53 degree C, respectively.

On the other hand, Fig. 10(a) shows the comparison of cerebral blood flow between thermal stimulus of 42 degree C and 53 degree C while Fig. 10(b) shows that for heart rate. From these figures, it is understandable that it is possible to estimate the thermal stimulus temperature using cerebral blood flow and heart rate.

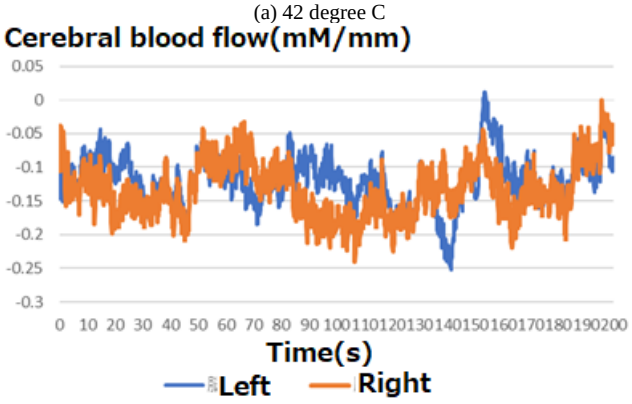
C. *Machine Learning with SVM for Estimation of Thermal Stress of Temperature*

Using these data, machine learning process is applied for estimation of thermal stress temperature based on SVM. The number of dataset of cerebral blood flow and heart rate is 20 for learning process. Table II(a) shows the results of the learning process for heart rate while Table II(b) shows those for cerebral blood flow. Percent Correct Classification: PCC for heart rate is 0.835 while that for cerebral blood flow is 0.898. In the previously proposed thermal stress detection by using size of pupil and pupil size changing rate, accuracy is around 0.8. Therefore, it is found that the proposed method for thermal stress temperature estimation is better that the previously proposed method with pupil related data.

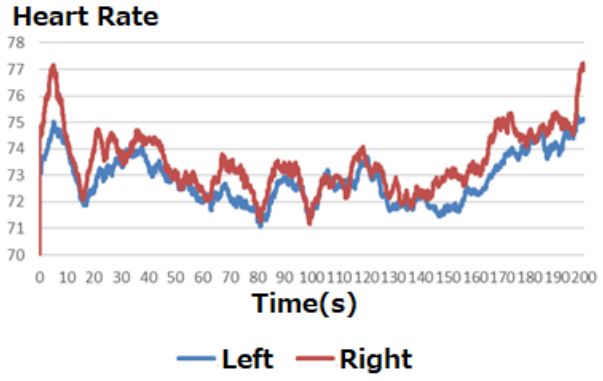
In this experiment, only two thermal stress temperature were tested. Therefore, there is an applicable limitation of the proposed method (up to 53 degree C of temperature). It is not clear that cerebral blood flow response against much higher water temperature of thermal stress and heart rate. Therefore, dynamic rage of the thermal stress temperature has to be expended for the next step of additional experiments. Furthermore, it might be exist some nonlinearity of the relation between cerebral blood flow and thermal stress temperature. Therefore, another experiment has to be conducted with much higher thermal stress temperature. These are applicable limitations of the proposed method.



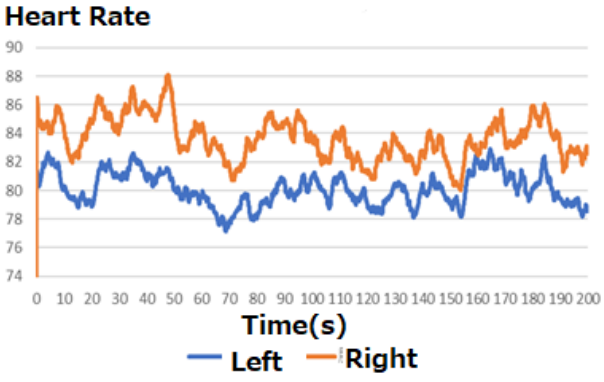
(a) 42 degree C



(b) 53 degree C

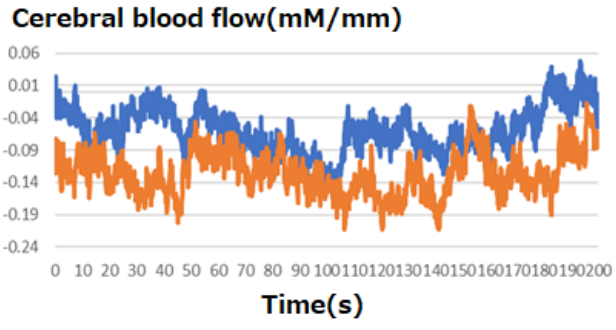


(c) 42 degree C

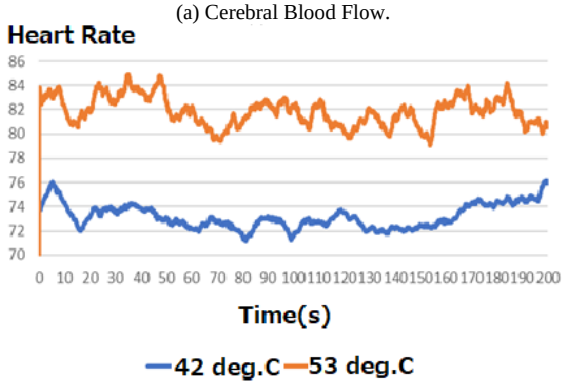


(d) 53 degree C

Fig. 9. The Acquired Cerebral Blood Flow and Heart Rate.



(a) Cerebral Blood Flow.



(b) Heart Rate.

Fig. 10. Comparison of cerebral blood flow and heart rate between thermal stimulus of 42 degree C and 53 degree C.

TABLE. II. RESULTS FROM THE SVM BASED LEARNING PROCESS FOR ESTIMATION OF THERMAL STRESS TEMPERATURE USING HEART RATE AND CEREBRAL BLOOD FLOW

(a) Heart Rate

Heart Rate	42 degree C	53 degree C
42 degree C	0.821	0.152
53 degree C	0.179	0.849

(b) Cerebral Blood Flow

Cerebral Blood Flow	42 degree C	53 degree C
42 degree C	0.894	0.098
53 degree C	0.106	0.902

IV. CONCLUSION

Method for thermal pain level estimation with heart rate and cerebral blood flow using SVM is proposed. Through experiments, it is found that thermal pain level is much sensitive to the cerebral blood flow rather than heart rate. Also, it is found that the performance of thermal pain estimation is much better than the previously proposed method with the number of blinks, the enlarging rate of pupil size.

As the results, it is found that Percent Correct Classification: PCC for heart rate is 0.835 while that for cerebral blood flow is 0.898. In the previously proposed thermal stress detection by using size of pupil and pupil size changing rate, accuracy is around 0.8. Therefore, it is also found that the proposed method for thermal stress temperature estimation is better that the previously proposed method with pupil related data.

V. FUTURE WORK

Further study is required for more experimental data with a variety of examiners. In order to validate the proposed method, more experiments with a variety of examiners are highly required. In particular, the other influencing factors to the thermal pain level changes such as pupil size eye motion, the number of blinks, the enlarging rate of pupil size. etc. have to be added as features of the SVM classification for improvement of the thermal pain level estimation accuracy.

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AUTHOR'S PROFILE

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Citizen Attention Web Application for the Municipality of Sabinas, Coahila, Mexico

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***Abstract*—The information systems are fundamental to perform the daily activities of any organization. There is an increasing dependence on organizations to use information technology to achieve their objectives. This article presents the web information system that has been developed and implemented as support to manage the administrative services needs required by the citizens of the municipality of Sabinas Coahuila, México, seeking to be served in the best way and to obtain information from Faster and reliable way to follow up. Previously we worked manually, keeping the records in a format in Microsoft Excel. For the development of the system the agile XP methodology was used. The creation of the database was in MySQL and the development in Visual Studio 2015, the part of web programming in ASP .NET and programming in C #. With the implementation of the system, there is currently electronic control of the requests made by citizens, providing integrity, availability and confidentiality of information; at the same time, streamlining the process of capturing and receiving applications in each department of the municipality of Sabinas, Coahuila, Mexico. In addition, the system provides statistics of the requests that were attended, those that are in process and those that were not attended.**

***Keywords*—Web system; citizen attention; database**

I. Introduction

Information systems offer improvements in all organizations, they help in decision-making and provide competitive advantages. In addition, they increase the organization capacity of a company.

The purpose of this article is to show the web information system that was developed and implemented as a support to manage the service requests required by the citizens of the municipality of Sabinas, Coahuila, Mexico, seeking to be served as best as possible and to obtain the information in a quicker and more reliable way for follow-up.

The function of an information system in an organization is to deliver timely and accurate information, with the appropriate presentation and formats, to the people who need it within the organization to decide or perform any operation at the time they need to have such information [1,2].

Mexican municipal governments, they have among their administrative activities to offer public services of potable water, drainage, sewerage, treatment and disposal of wastewater, public lighting, collection, transfer, treatment and final disposal of urban waste, public safety, transit and transport, public works, etc. [3,4] cited in [5,6].

Next, the process that was carried out in the single window of the presidency of the municipality of Sabinas Coahuila, Mexico is described. Every day requests are received from citizens, asking for lamp changes, cutting of trees, scholarships for studies, paving of streets, repair of sewers, etc.

The areas involved in resolving what the citizen requires are located in different buildings and the applications are received in the single window area located in the municipal presidency. These requests are made personally by the citizen or can be made by phone calls which were registered in a format made in Microsoft Excel. Fig. 1 shows the format in which the control of the requests was kept until there was availability of personnel to indicate the pending to each area or department, which caused a delay in the solution of the citizen's requests.

Some of the problems that were presented in the process of citizen care were the following:

- The requests received by the citizens were registered in a single computer, which meant that they were not channeled and reported on time to the agency in charge.
- To respond the petition requested by the citizens, it took up to two days after for the request to arrive at the unit to which it belongs.
- It was difficult to make reports of the requests that were presented in the department of attention to the citizen, because this information was in each unit and this was not reported periodically to the department of citizen attention. Due to this situation it was difficult to know how many requests were attended, how many requests were in process and how many requests were not attended
- The information was not updated, so it was impossible for the citizen to be aware of the progress or status of their request.

As described above it is pertinent the development and implementation of a web system to solve the problems that arise in the public administration of the municipality of Sabinas, Coahuila, México.

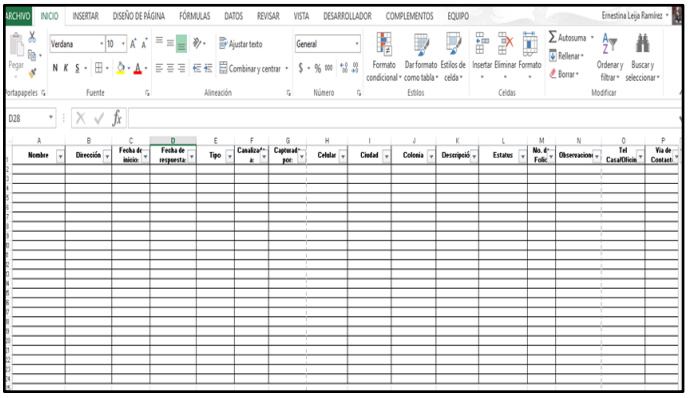

Fig. 1. Request Control Format.

With the development of this system will have the main characteristics of information, such as integrity, availability and confidentiality. In addition, the system will facilitate the storage and management of information.

The system will allow having control of the requests made by the citizens, having as benefit the mobilization in the process of capture and reception of the requests in each department of the municipality of Sabinas, Coahuila, México.

The system provides statistics of the requests that have already been attended, those that are in process and those that were not attended.

By automating the process, you will also have the benefit that the capture of the requests can be done from other buildings, always integrating the information in the same system.

In the first part of the article an introduction is presented, later theoretical foundations, methodology of system development, results, conclusions and finally the references.

II. Theoretical Fundamental

A. Software Engineering

According to Rubio, Valencia, Peña and Rodríguez [7,8] cited in [9,10], technology is defined as "the means through which scientific knowledge is transferred to the solution of concrete problems in an effective manner".

García [11,12] cited in [13] states that software engineering is defined as a technological and management discipline related to the creation and maintenance of high-quality software products, developed on time and at minimum cost.

Software engineering is an engineering discipline that is interested in the production of software, from the specification of the system to its maintenance after it is put into operation. Software engineering has a systematic approach and considers the cost, time, reliability and customer needs [14,15].

Every software development process focuses on the technical aspects such as the specification, development, validation and evolution of the software providing transparency and flexibility [16,17].

B. Web Applications

On the other hand Arroyo, Rico, Barrón and Aguirre [18,19] cited in [3,4], comment that web applications automate part of the administrative activities, storing and organizing information in such a way that efficient searches and concrete reports can be carried out according to the needs of each of the profiles, as well as providing the benefit of access to timely information from anywhere.

Redrován, Loja, Correa and Piña [20,21] cited in [22,23], they define as a web application all software that allows to be processed and stored within web servers and then accessed via browsers.

The common feature of web applications is to centralize the software to facilitate the maintenance and updating of the systems. This way you avoid having copies of the applications in all the workstations, facilitating the updates and ensuring that the web application works correctly [24,25].

According to Pressman [26,27], most web applications have the following characteristics:

- They are in a network and must meet the needs of several clients.
- It can be accessed by several users at the same time.
- The number of users of the application varies from day to day.
- The user of the application should not wait too long to access the client part of the system.
- The main function of many web applications is to show the end user the content of their information in the form of text, audio, video or graphics.
- The aesthetic presentation and quality of the information are very important.
- Web applications must be continually updated.
- They must reach the market quickly.
- Security measures must be taken as they are available for access via a network.

C. Agile Methodologies

In 2001, the manifesto for the agile development of software is signed. This manifesto arises from the collaborative work of 17 important software developers [16,17].

This manifesto expresses that new ways of developing software have been discovered, due to their experience and with the help they have provided to third parties, where they have learned to appreciate the following:

- Individuals and interactions about processes and tools.
- Software running on extensive documentation.
- Collaboration with the client on contractual negotiation.
- Response to change about following a plan [28].

The goal of agile models is not to solve the challenges of software engineering; however, it seeks to provide a better development environment. Practitioners of these methodologies comment that they are the ones that best adapt to the constantly changing needs of business.

Agile models make use of user stories to capture the client's needs in a software project, they are written in simple language which helps communication between the client and the development team [16,17].

Agile methodologies are identified by iterative development, simplicity in implementation, frequent deliveries and prioritization of requirements, customer-dependent development features, and cooperation between developers and customers. Agile methodologies consider requirements to change during the development process [29,30].

D. Extreme Programming XP

The extreme programming is one of the methodologies of agile development of wide used software. The success is due that first we consider the satisfaction of the client, delivering the software according to their necessities, where the cooperative work is relevant with the client and the team of development.

Every project of software that is developed through this methodology considers essentially the communication, simplicity, feedback, respect and courage. The extreme programmers are in constant communication with their clients and programmers colleges, they accept commentaries at the moment to try their software since the first day, they deliver the system to the clients as soon as possible and they do the required changes [31].

III. Methodology

XP agile methodology was used for the development of the system. XP is an agile methodology that is based on customer satisfaction, so there must be a fluent communication between the client and the development team.

Fig. 2 details the process for developing the web system. It began with visits to the citizen attention department to clarify the requirements of the system and have a general vision of what was needed.

This was documented as the specification of software requirements based on the IEEE 830 standard. Subsequently, other visits were made to the client for the realization of user stories, which were performed between the client and the development team. In each story the acceptance criteria were specified.

Once the user stories were elaborated, they were sorted by priority and the iterations were organized in order to start with the development.

When starting with the iteration simple designs were made always thinking that the design should be able to adapt to probable changes that the client requests.

For the coding it started with the creation of the database in MySQL and the development in Visual Studio 2015, the part of the web programming in ASP.NET and the programming in C#.

It was established what should be tested during the development and the programming was applied in pairs, remembering the recommendation that one programmer be the main programmer and the other focus on the quality of the software.

During the iteration development the team did the code tests, the modules integration tests and the client proved that the module will perform what he requested. When the client detected a failure, user histories were re-created or those that already existed were modified and reprogramming of the iterations was necessary.

At the end of each iteration, the process is started again, and it is repeated until the development of all the iterations is finished, resulting in the final system, which will be hosted on the contracted server.

Among the main features of the application is to ensure confidentiality, integrity, availability of information through the password assigned to authorized personal for accessing the system.

Fig. 3 shows the relational model, which shows the relationships between the tables in the database.

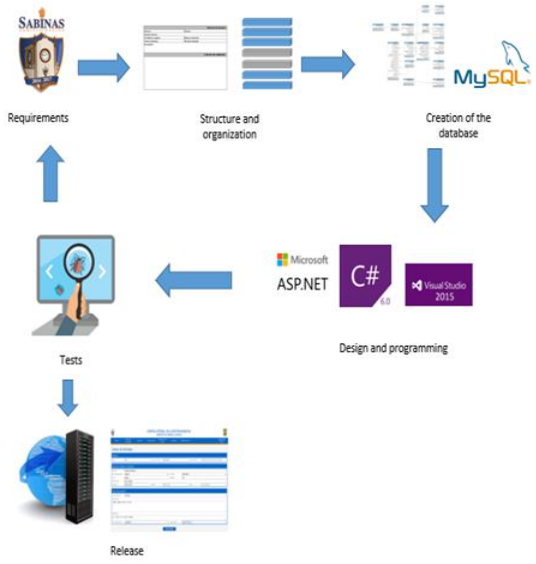

Fig. 2. Application Development Process.

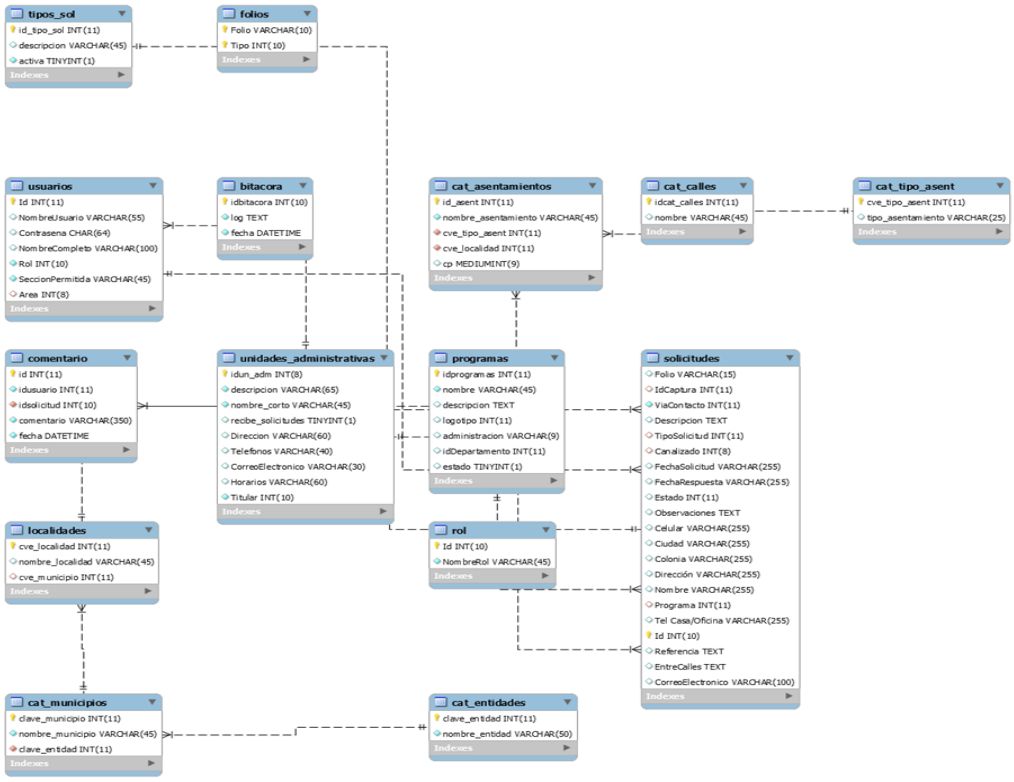

Fig. 3. Relational Model of the Database.

Table 1 shows one of the user stories, to start the development of the system.

TABLE. I. USER STORY ONE

Historia de Usuario				
Número:	1	Usuario:		Administrador
Nombre historia:		Agregar usuario		
Prioridad en negocio:		Alta	Riesgo en desarrollo:	Alto
Puntos estimados:	100	Iteración asignada:		1
Descripción:				
Como administrador deseo poder agregar usuarios				
Criterios de validación				
a. Los campos no deben estar vacíos.				
b. El área puede ser cualquiera de las siguientes: contraloría municipal, DIF municipal, dirección de comunicación social, dirección de desarrollo económico, dirección de desarrollo humano, dirección de desarrollo rural y medio ambiente, dirección de ecologia, dirección de prevención y seguridad ciudadana, dirección de servicios públicos, dirección de urbanismo y ordenamiento dirección territorial, dirección técnica de planeación, presidente municipal, secretaría de participación ciudadana, y ordenamiento terri-secretaría del ayuntamiento, SIMAS o tesorería municipal.				
c. Los roles son administrador o departamento.				
d. La contraseña se debe introducir dos veces para verificar que sea correcta.				
e. La contraseña debe ser encriptada en formato SHA1.				

Fig. 4 and Fig. 5 show some of the screens that were designed in Pencil Software, to show them to the user, and make the necessary modifications before starting with the programming of the system.

Fig. 4. Login Screen.

Fig. 5. Administrator Input Tray Screen.

IV. RESULTS

The developed system was integrated as a module of the system of integral control of the municipal management inside of the option of the citizen attention. Following we show some relevant screens of the system.

To have access as an administrator, first, it is necessary to access the municipality's website. In the upper right side, you can see the section to log in as shown in Fig. 6.

Is necessary to introduce the user, the password and lately click the button to enter. It is necessary to validate the user and the passwords that are in the data base, in the other side emit a message and do not allow the access.

Once the system is accessed it takes you to the inbox of the administrator as shown in Fig.7. On this screen, the status of the requests that reach the department is listed.

As previously mentioned, the system was integrated as a module of the system of integral control of the municipal management inside of the option of the citizen attention. This can be seen in the Fig.8.

Fig. 6. Login Screen.

Fig. 7. Inbox Screen Administrator.

Fig. 8. Citizen Attention Module Menu Screen.

As department, you have the option to change the status of the received requests to in process; If the requests are already in process you can change their status to completed or unfinished and add a comment. If requests arrived in the inbox that do not correspond to the department, the administrator can reanalyze the requests to the corresponding department. When done, the request disappears from the administrator's inbox and appears in the inbox of the department or area that was selected. The Update Requests button will be clicked each time the administrator wants to see if new requests arrived.

Fig. 9 shows the capture of the requests; the folio is automatically assigned as well as the date and the user that captures.

When capturing the data of the citizen or institution that makes the request, the city can be selected from a list of populations that are already captured. When the city is selected the corresponding neighborhoods are activated to choose the one of the citizen.

In the data of the request the contact way can be: personal, telephone, SMS, web, e-mail or others.

The type of request and channeling is selected from the list of options that are already captured within the system.

The system allows searching by name of the citizen, colony, city or town, street or telephoning so that if the administrator wants to know all the requests received from a particular neighborhood or a citizen, here you can get the information.

As can be seen in Fig. 9 the search criteria are written and then the button "Show requests" is clicked to show the requests that meet the criteria. Again the folios of the applications appear as a link, so that if you want more information of any of them it will be enough to select the folio.

The system allows the administrator to view the statistics of the requests by day, month and year. Figure 10 shows the statistics by year.

In addition, the administrator can view the graphs of the requests by area and by month. In both, the pipeline area is selected, as well as a start date and a finish date for the charts. This is shown in Fig. 11.

The system allows the citizen to follow up on his request by accessing the municipality's website. Within the web page, in the upper left part you must write the folio of your application and then press enter, this is shown in Fig. 6.

The limitations presented by the project are those of the infrastructure, since being a System that will be used through the internet, it is necessary that you always have access to the same; If at any time there is no internet, you will not have access to the system.

Another limitation is that, being a web-based system, it is necessary to hire a service Web hosting so you will have to make a payment by the municipality, this could be considered as limiting since the payment is annual.

Fig. 9. Requested Capture Screen.

Fig. 10. Screen to Show the Total of the Annual Requests.

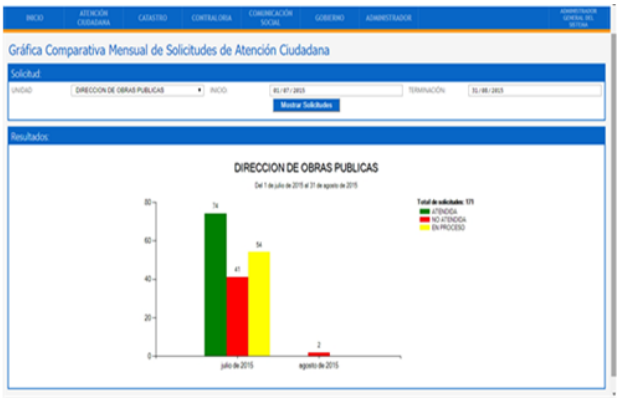

Fig. 11. Monthly Comparative Graph of the Requests.

One more limitation that could be observed when the system was implemented in the municipality of San Juan de Sabinas Coahuila, Mexico is the resistance to use it by the personnel involved because although they were given training for their use in the end not all used.

V. Conclusion

The system was developed for the 2014-2017 administration and was successfully implemented in the municipality of Sabinas, Coahuila, Mexico. With its implementation, it is possible to have 100% control of the applications submitted by citizens.

The system provides the statistics of the requests received, in process, attended and not attended. These are obtained at the time the option is selected and provides the updated information.

The system was also offered to the municipality of San Juan de Sabinas, Coahuila, Mexico and was accepted. In this municipality, the system was installed as an Electronic Window, changing only the colors and logos of the system according to their requirements.

The system has the main characteristics of the information, such as integrity, availability and confidentiality.

It is important to mention that the system finished its function with the 2017 administration. However, it was submitted to the current administration 2019-2021 and was approved, so the necessary changes were made according to the new dependency requirements.

Each system has an opportunity for improvement; in this case the improvements that will be made are adding the CRUDs (Create, Read, Update and Delete) in the pipeline areas and locations. He will make adjustments to its architecture, removing some fields from the database that are not required.

VI. Discussion

The system developed and implemented has been of great help in decreasing the time in sending the requests to each department involved and in generating the statistics for the report of the work performed.

However, for the system to produce the correct results, it is necessary that all personnel is involved in the use of it. In addition, he agrees to feed him with the follow-up of each request changing its status to in process, attended or not attended, since from there the statistics will be obtained.

On the other hand to be a system for a municipality, when the management of each administration ends it has been necessary to offer the incoming administration the use of the software and explain its functioning.

It is relevant to mention that there was no instrument for measuring the system as such since an agile methodology was used for its development. He was interacting with the person who requested the development of the system once a week reviewing what was scheduled and she is determined if it was really needed.

When releasing the system the same person was informing its use and some adjustments that were made to do, the subsequent administration was very enthusiastic about the software and they decided to continue using it, adapting the colors and logos of the new administration.

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Usability of "Traysi": A Web Application for Tricycle Commuters

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***Abstract*—This study measured the usability of a web application for tricycle commuters that was developed using Hypertext Markup Language (HTML), Cascading Style Sheet (CSS) and Javascript (JS) with the aid of Google Artificial Programming Interfaces (APIs). Toward this goal, the effectiveness, efficiency and user satisfaction were measured using common usability metrics. The effectiveness was measured in terms of task completion rate and user errors while efficiency was measured in terms of time on task. For user satisfaction, the post-task questionnaire, Single Ease Question (SEQ), was used. In order to check whether the web application will be usable even for first time users, the usability test was conducted three times. The result revealed that the usability of the web application is acceptable on the first trial. However, the usability improved on the next used which is evident on the third trial that yielded a 93.33% task completion rate with only one user error. The average time on task on every trial was lower than the maximum acceptable task time and the user satisfaction was high ($\bar{x} = 6.00$). Thus, the web application was highly usable in doing its intended purpose especially if it is repeatedly used.**

***Keywords*—Tricycle; usability metrics; web application; fare calculation; Google API**

I. Introduction

In most developing nations, motorcycles are one of the primary modes of transportation. In the Philippines, local public transport in the form of tricycles exists [1]. The design differs from one town to another [2] but is mostly made of a motorcycle fitted with a sheet-metal body frame covered by roof canvas [3] to accommodate local travelers. Tricycles provide services by transporting a commuter [4] to major streets and barangays with low fuel consumption [5]. The tricycle is notable for their role as gap fillers [6]. They exist mostly to fill service voids left by busses and other formal public transport vehicles.

Tuguegarao City, a developing town in the Philippines considered to be the heart of Region 2 where the Regional Offices are located, still uses the tricycle as the primary mode of transportation. It was first introduced in the early 1960s and by 2010 it has reached a shocking number of 12,000 tricycles going around the city. Unfortunately, Tuguegarao has been branded as the city of English-speaking tricycle drivers because of the recorded cases of abuse by drivers. Some tricycle drivers in the city collect unjust fares from the passengers [2] that present a negative image to Tuguegarao. Although the local government has been working hard to apprehend these abusive drivers, there are still some that are overcharging. Most of the time, those people who are new to the place fall victims to this wrong practice by the abusive drivers. The government has imposed the posting of fare rates inside the tricycle fronting the passenger [2] but drivers who charge more than the prescribed fare rates still exists. It seems that the only way to stop this practice is to educate the passengers regarding fare rates. Moreover, the use of automated fare systems to tricycles is still farfetched since this will be viewed as additional expenses to both drivers and passengers.

In educating passengers about the prescribed fare rates, researchers looked at the possibility of using technology. A real-time trip information service was developed in Singapore for passengers to determine the estimated duration and fare of a trip that they will take so that they can plan their time and budget accordingly as well as serving as a safeguard against abusive drivers who might take longer than expected routes especially when servicing tourists [7]. In the Philippines, a web application called Sakay.ph [8] is now used by many passengers in Metro Manila to compute the fares for the given origin and destination point.

Most of the existing studies that developed an application for commuters only incorporates buses, trains, and jeepneys in the travel guide. Although there are some applications for tricycle commuters developed for specific places, none have studied the usability of such applications to better understand how real users interact with the apps which can serve as a guide to improve the application based on the results. This study attempted to address this gap. A web application called "Traysi" was developed and its usability in terms of effectiveness, efficiency and satisfaction was evaluated to determine if it can provide the tricycle commuters a usable application to query the fare and at the same time get the travel direction and tricycle terminal location address when going to a certain place.

The design and development of the web application were done using HTML, CSS, JS and Google APIs. For the usability testing, a timekeeper and an observer were involved to get an accurate result. The results of the usability testing can serve as a guide for developers to improve existing applications. Future developers will also be benefited as they will have an idea on to what aspect of the design, they will focus more on their own version of the application for tricycle commuters.

II. METHODOLOGY

A. Description of the Web Application Evaluated

The web application "Traysi" is a tricycle fare calculation web application that uses the latest fare matrix approved in Tuguegarao City. The minimum regular fare imposed by the city government was set to be Php12.00 that corresponds to three (3) kilometers. The distance covered from origin to destination in each individual trip is different, so to address this, the city government approved the petition of the Tuguegarao City Tricycle Operators and Drivers Association (TCTODA) wherein a ₱ 0.50 per kilometer of the succeeding kilometers (after the three (3) kilometers) will be added to the fare.

The web application was developed using HTML, CSS and JS. HTML is a typical markup language used in developing the web application. With CSS and JS, the functionality and interface design of the web application was formulated. Moreover, several Google Maps subroutine definitions called API were utilized in the development of the web application. The APIs include Maps Embed API, Distance Matrix API, Directions API, and Places API. The web application is powered by 000webhost, a free web hosting site.

The pinning of origin and destination were facilitated by Google Map's autocomplete place handler as shown in Fig. 1-a. This handler speeds up the interaction between the web app and the user. It predicts the place a user intends to enter after a few characters have been typed into the origin and destination text field. After the origin and destination have been identified, the web application displayed the actual direction on the embedded Google Map as shown in Fig. 1-b. The calculated fare is revealed when the user taps the Calculate button. Also, the tricycle terminal location address of the barangay where the user wants to go was shown at the bottom of the web application as shown in Fig. 1-c.

B. Usability Testing

Several systems are evaluated to determine if its suites the need of the users. The evaluation of a system is oftentimes done by measuring its usability. The goals that a particular study wants to achieve are where the choice of measures depends [9]. The definition of usability from ISO 9241-11 is "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use" [10]. Usability is commonly measured by the three metrics: effectiveness, efficiency, and satisfaction [9][11][12][13]. The usability of the web application named "Traysi" was determined and analyzed using these three metrics.

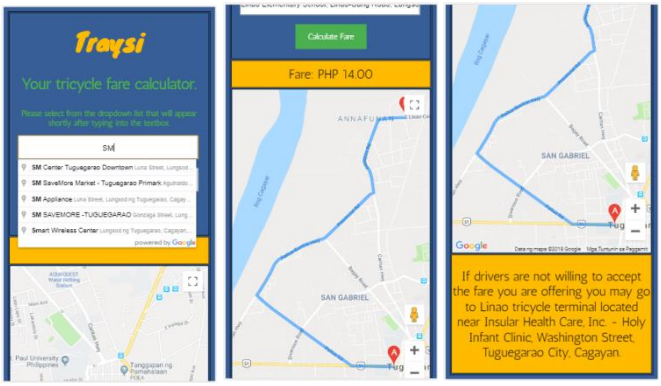
Effectiveness is defined in the ISO9241-11 as "the accuracy and completeness with which users achieve specified goals". This usability metric only takes into account the extent to which a goal was achieved, not on how it was achieved. It can be calculated by measuring the task completion rate [9][11][12][13]. The task completion rate is considered as a fundamental usability metric. It can be determined by assigning a binary value of '1' for every achieved task and '0' for the unachieved task by a participant [11][13]. In the study, task completion was calculated as a percentage [13] using (1) wherein NTCS is the number of tasks completed successfully and TNTU is the total number of tasks undertaken.

$$Task\ Completion\ Rate = (NTCS / TNTU) \times 100\% \quad (1)$$

Another measurement of effectiveness involves counting the total errors [9][11][12] a participant makes when completing a task. This is important because it provides diagnostic information [12] on the system being evaluated. The errors can be of many forms like mistakes, unintended actions, slips or omissions that a participant makes while performing a task.

Efficiency is another important usability metric that refers to the resources spent in achieving a task [14]. It can be measured in terms of the mean time taken to achieve a specific task [9][13]. The most common measure of efficiency in the evaluation of usability is time on task [9][15]. A stopwatch was used in getting the time on task for every user. The average task time for every trial was estimated using the geometric mean. The geometric mean was used since the study has a small sample size. It was recommended by a recent study [16] for small sample sizes ($n<25$) because it showed consistently less error and bias than the median or the trim-top mean.

Satisfaction is the subjective response of the user after a usability test [9][13]. It can be measured through standardized questionnaires that are built using a Likert scale [9]. A variety of questionnaires can be used to measure user satisfaction but the cheapest and quickest to administer [17] is Single Ease Questionnaire (SEQ). SEQ is a Likert scale variant that is found to be more reliable [18] in small sample sizes. This task level satisfaction metric was given after the users attempted the task regardless if the task was completed or not. The SEQ is composed of only one question that has seven levels as shown in Fig. 2.



(a) (b) (c)

Fig. 1. (a) Autocomplete Place, (b) Tricycle Direction and Fare, (c) Tricycle Terminal Location Address.

Overall, the task was?

Very Difficult						Very Easy
1	2	3	4	5	6	7

Fig. 2. The Single Ease Question (SEQ).

C. Participants of the Study

The research participants of the study consisted of 15 individuals that were conveniently selected to use the web application using their own mobile phones that have an internet connection. These participants are regular tricycle passengers in Tuguegarao City.

D. Data Gathering Tools

For the usability data, a timekeeper used a stopwatch in recording the time spent by a participant in using the web application. Meanwhile, an observer was tasked to record the errors committed by the participant. This observer also determined if the task is completed or not. The usability data for each trial were all recorded in a Microsoft Excel workbook.

E. Data Gathering Procedure

The data gathering in the study was done separately per participant. The usability measures were collected through experimental methods. Every participant was informed that they may not complete the task and may close or reload the web application anytime they want to. The participant was given the task to use the application by inputting their preferred origin and destination on the web application. The time spent doing the task was collected by a time-keeper. Meanwhile, the observer recorded the number of errors the participant committed while doing the task. The participant would inform the observer upon completion of the task. After doing the task, the participants were asked about the satisfaction in doing the task. The usability testing was done three times to determine if the results changes on the next use.

III. Results and Discussion

The study measured the usability of a web application of tricycle commuters named "Traysi". Usability was measured in terms of effectiveness, efficiency, and satisfaction. Reference [17] mentioned that simultaneously measuring these three dimensions provides the best quality data in usability studies.

A. Effectiveness

Fig. 3 describes the effectiveness of the web application based on task completion rate. On the first trial, 11 out of 15 participants were able to complete the task of calculating the fare. It had to be noted that these participants were first time users of the web application being studied. The task completion rate improved on the second trial wherein 12 of the participants were able to successfully complete the task. On the third trial, a significantly higher completion rate was computed because only one participant was not able to successfully complete the task.

Majority of the participants on the first trial were able to finish the task even though it was their first time using the web application. This is because the web application had short, succinct and self-describing text content to give participants the idea of what kind of data to enter in the textboxes. This is one of the desirable factors for a good user interface [19][20]. Additionally, the design of the web application is user-centered [21] wherein users can run the application without prior training. The second trial had a much higher completion rate but still, some of the participants were not able to complete the task despite completing it on the first trial. They were trying something out that resulted in an unsuccessful task. The third trial, however, had a very high task completion rate which is over the average task completion rate benchmark of 78% used in other studies [22][23].

Some errors were made by the participants when attempting to complete the task of calculating fare as shown in Fig. 4. The greatest number of errors were recorded on the first trial. This, however went down on the second and third trial. The user errors included not selecting a place from the drop-down list, selecting a place outside the town, no place selected in the origin nor destination, and accidentally going back to the previous page. Some of the participants committed errors on every trial. But the number of errors still went down on the next use. This showed that when users already had knowledge of using the application, there will only be a small chance of them committing the same error again. Moreover, user errors are inevitable and are often observed in human-computer interaction systems [24][25].

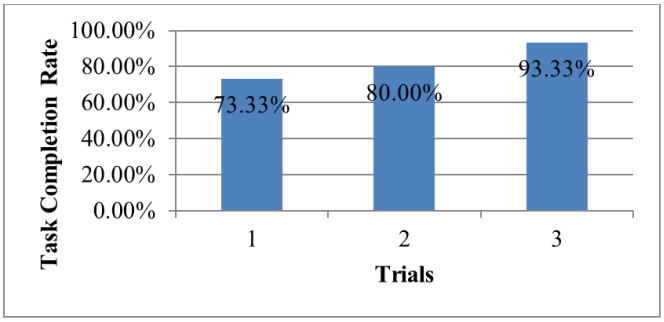


Fig. 3. Task Completion Rate from Each Trial.

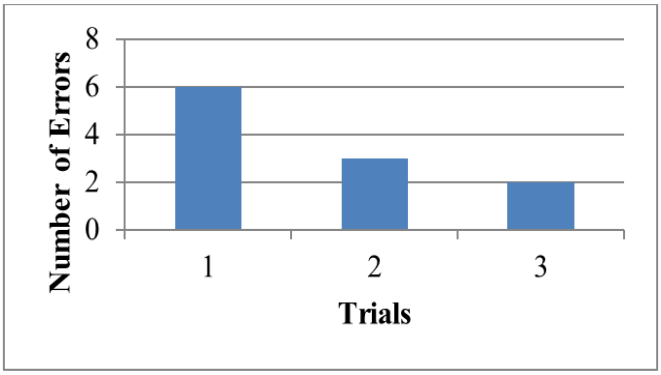


Fig. 4. Number of user Errors from Each Trial.

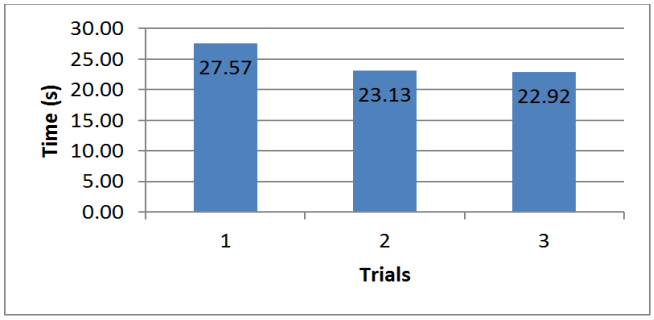


Fig. 5. Average Time on Task from Each Trial.

B. Efficiency

The average time on task of the participants from each trial is presented in Fig. 5. The first trial yields the highest average time on task, nevertheless, it decreased on the succeeding trials. The difference between the second and third trial is very small. This was due to the slow internet connection that made the participants wait for the information to load even if they already knew how to use the web application.

The average time on task of the participants from all the trials were lower than the maximum acceptable task time which is 40.98 seconds, 34.58 seconds and 36.65 seconds, respectively. The maximum acceptable task time is computed using the method proposed by [24]. It is done by removing the times from failed tasks first then removing the times where satisfaction scores are less than 5.6 for 7-point scale and finally getting the 95th percentile of the remaining times to arrive at the specification limit.

The positive result from the efficiency testing can be attributed to the card base design in the user interface wherein participants were only limited to one screen so that they may visualize the data well and not worry with where to go or what to click next. The implementation of card base design method bridged the gap between interaction and usability [19] in a synchronized manner to create a consistent user interface design across devices. The only problem though was the slow internet connection which makes the results to load longer than expected. This was also a problem with another internet-based system [14] because the Philippines is one of the countries with the slowest internet connections in Asia.

C. Satisfaction

Fig. 6 describes the satisfaction of users in using the web application particularly on doing the task of calculating tricycle fare. Only some of the participants were somewhat satisfied on the app in the first trial ($\bar{x}$= 4.73) but eventually giving a high satisfaction on the second trial ($\bar{x}$ = 5.47) and third trial ($\bar{x}$ = 6.00). Four participants perceived that the task was very easy after using the web application for the third time.

It was evident in the results that the user satisfaction was associated with task completion and errors. Those participants that were able to complete the task and did not make errors perceived that the task was very easy while those participants that were not able to complete the task and made errors perceived that the task was difficult. This is consistent with the study of [17] where the task completion rate and error correlate with satisfaction.

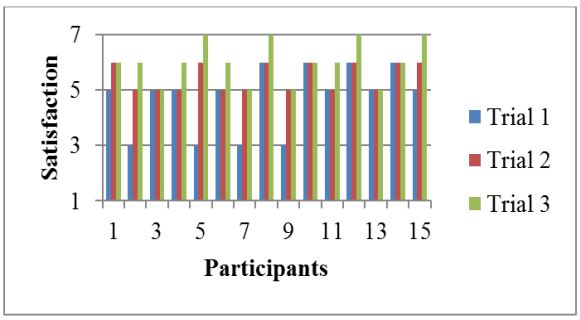


Fig. 6. User Satisfaction on the Ease of use of the Web Application.

IV. Conclusion

This study determined if the web application for tricycle commuters named "Traysi" can provide the tricycle commuting public a usable application to query the fare and at the same time get the travel direction and tricycle terminal location address when going to a certain place by measuring its usability. It was only limited to the usability metrics that include effectiveness, efficiency, and satisfaction. Other software metrics were not used to evaluate the web application. The effectiveness of the web application in calculating the fare, displaying the travel direction and providing the tricycle terminal location address was evident based on the high task completion rate and low number of user errors even on the first used. Also, the web application was efficient in displaying the information on the screen despite slow internet connectivity. The participants also perceived that the task of using the application by inputting the preferred origin and destination is easy. Based on the findings presented, the web application named "Traysi" has a high level of usability. Moreover, this level of usability increases on the next use of the application.

For future works, a feature which will automatically show the tricycle terminal location in the map by clicking on the information provided can be added in the app. Additionally, a mobile application version can also be developed. In future usability testing, it should be done in a lab where all participants will do the task at the same time to get a more accurate result.

Acknowledgment

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A Decision Tree Approach for Predicting Student Grades in Research Project using Weka

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***Abstract*—Data mining in education is an emerging multidiscipline research field especially with the upsurge of new technologies used in educational systems that led to the storage of massive student data. This study used classification, a data mining process, in evaluating computer engineering student's data to identify students who need academic counseling in the subject. There were five attributes considered in building the classification model. The decision tree was chosen as the classifier for the model. The accuracy of the decision tree algorithms, Random Tree, RepTree and J48, were compared using cross-validation wherein Random Tree returned the highest accuracy of 75.188%. Waikato Environment for Knowledge Analysis (WEKA) data mining tool was used in generating the classification model. The classification rules extracted from the decision tree was used in the algorithm of the Research Project Grade Predictor application which was developed using Visual C#. The application will help research instructors or advisers to easily identify students who need more attention because they are predicted to have low grades.**

Keywords*—Data mining; classification rules; decision tree; educational data mining; WEKA

I. Introduction

The developed world has experienced rapid increase in technology and information over the past few years. The Information Age has led to speedy flow and availability of information. This information comes from the massive data that are being extracted from different databases. When this data is analyzed using the statistical methods that are continuously being refined and perfected [1], valuable answers to business, social, environmental and educational problems are being discovered. In discovering valuable answers to many problems, new technology has emerged affecting human life in various spheres directly or indirectly [2]. This technology is called data mining or knowledge discovery in databases (KDD). Data mining is utilized to extract important information from complex databases [3][4][5]. The primary function of data mining is applying different methods and algorithms to preprocess, classify, cluster and associate the data to discover useful patterns [6][7] of stored data.

Education is one of the areas that benefited most in the emergence of data mining. This kind of data mining is called Educational Data Mining (EDM). It is used by educational institutions to provide better service to their students. Data mining also allows schools to use stored data to improve teaching and learning processes [4]. Educators will know so much more about the student's process which can improve students' performance in school. Moreover, it can be used to make data-informed decisions about what should people be doing for education. EDM can be used in many ways but perhaps the most common application of EDM is predicting a student's academic performance. Several studies along this area predict students' achievement in their subjects like mathematics [8], physics, chemistry, and biology [9]. All of these studies have the goal to identify at-risk students and identify priority learning needs for different groups of students [4] to create interventions and improve their performance.

Research is a subject in college that is embedded in the curriculum of any course. The activities in this subject are highly considered as a high-impact educational practice [10]. It is where lifelong learners' vital skills and attitude are being cultivated through inquiry [11][12]. The practice in most schools is that students are guided by an adviser when undertaking a research project during a specific period [13]. Students need to develop the skills necessary [13] for their research process especially in applied disciplines such as engineering, architecture and information technology. For example, computer engineering students are required to have a high level of proficiency in programming. Although skills are necessary to perform well in research, other factors like backlog and research method grade may serve as an indicator to student's performance. Backlogs are often considered as one of the factors in predicting students' academic performance [4][14] because this is considered as a burden to students. The grade in research method also serves as the basis on how the student will perform in a research project because all the basics of research are being taught in this subject. The gender of student doing the research is also important most especially in engineering disciplines because sometimes research projects being built are too heavy for female students to handle.

Although there are already studies that predict student's academic performance in subjects like math and science, none have studied about predicting a student's performance in an undergraduate research project course. This study addressed this gap. It proposed a classification model specifically decision tree algorithm in predicting the possible grade of a computer engineering student in Research Project.

The data mining software WEKA was utilized in the preprocessing of data, construction of classification model, and interpretation of the model. The decision tree generated was used to create a grade prediction software application. This software can be used in identifying students who needs academic counseling so that their performance in research will improve sufficiently and they will be able to produce a publishable or patentable research project output.

II. Methodology

A. Data Mining Software Utilized

The data mining software WEKA shown in Fig. 1 is programmed using Java. This software was developed at the University of Waikato in New Zealand [16]. It has many machine learning algorithms for different data mining tasks. It contains features that are used in data preparation and preprocessing, classification, clustering, association rules mining, regression, and visualization. WEKA is widely-used free software licensed under GNU General Public License (GPL). This software is not only recognized as a landmark system in data mining but also in machine learning [15]. Academia and business circles have been using this software for different purposes.

B. Collection and Preprocessing of Data

The researcher has been handling the Research subjects of the computer engineering program for the past four years. The grades of the students from the research subjects, particularly Research Method (RM) and Research Project (RP) were used as attributes for the project. RM is a pre-requisite subject of RP. It served as one of the attribute predictors in the model. On the other hand, RP served as the attribute class being predicted in the classification model. Three other attribute predictors were used which includes gender, backlog, and programming proficiency. The RM grades, RP grades, gender, and backlog data for the project has been collected from the University of Saint Louis Tuguegarao. The backlog was traced based on the year the student graduated. If the student graduated semester/s after completing RP, it means that the student still has backlogs. The programming proficiency was filled out manually by the researcher based on the student's programming proficiency level. The levels were Fundamental Awareness (basic knowledge), Novice (limited experience), Intermediate (practical application) and Advanced (applied theory). The RM and RP grades were converted into letter grades which includes A (92%–100%), B+ (87%–91%), B (83%–86%), C+ (79%–82%), C (75%–78%). This letter grade conversion was based on the letter grade equivalence of Ateneo de Manila University, except that it was only up to C since grades below this are considered failed.

The data were first collected in Microsoft Excel worksheet and initial preprocessing was done. The dataset contains 133 instances wherein each instance contains the five (5) attributes. The possible values of the different attributes are shown in Table I.

C. Classification Model Building

After the data collection and preprocessing, the classification models were finally built. The classifier used in the study was the decision tree. Decision tree has been used in numerous studies on prediction of student's academic performance [17][18][19] because classification rules can be derived in a single view. The Random Tree, RepTree and J48 decision tree were used for the model construction. Fig. 2, Fig. 3 and Fig. 4 shows the constructed decision tree for Random Tree, RepTree and J48, respectively. In the decision trees, the leaf node was represented by rectangle while the root node was represented by an oval [17].

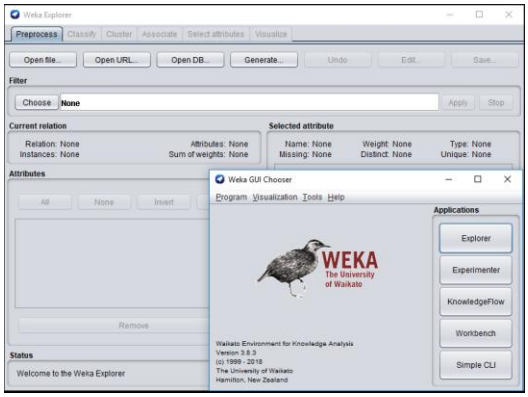

Fig. 1. The Graphical user Interface of WEKA.

TABLE I. The Attributes used in the Classification Model

Attributes Name	Possible Values
Gender	Male, Female
Backlog	Yes, No
Programming Proficiency	Fundamental Awareness, Novice, Intermediate, Advanced
RM Grade	A, B+, B, C+, C
RP Grade	A, B+, B, C+, C

III. Results and Discussion

A. Model Evaluation and Interpretation

Cross-validation was used to measure the predictive performance of the classification models. It was also used in previous studies [14][15][16] because it checks how a model performs when new data set or test data are used. Cross-validation is important because when a model is fit, it is usually fit only to the training dataset. With cross-validation, the prediction accuracy of the model can be seen when there is new data. In this study, the 10-fold cross-validation feature of WEKA was used to evaluate the classification models. The three different decision tree algorithms Random Tree, RepTree and J48 were compared. The result of compression is depicted in Table II for the cross-validation method. The decision tree with the highest accuracy was achieved by the Random Tree decision tree algorithm. The over-all accuracy of this classification model was 75.188% which means out of the 133 student grades in RP, 100 were correctly classified. This accuracy is better than that of previous studies [14][15][18] that also conducted prediction of student's academic performance but in general. The RepTree and the J48 were less accurate with both having 69.925% accuracy. From the results, it is noticeable that the accuracy of the classification models is acceptable but not very high. More samples should be collected and more attributes should also be added to have a very good classification model.

TABLE II. Acuracy of the Decision Tree Algorithms

Decision Tree	Accuracy (%)	Build Time	Correctly Classified Instances	Incorrectly Classified Instances
Random Tree	75.188	0.00	100	33
RepTree	69.925	0.02	90	43
J48	69.925	0.02	93	40

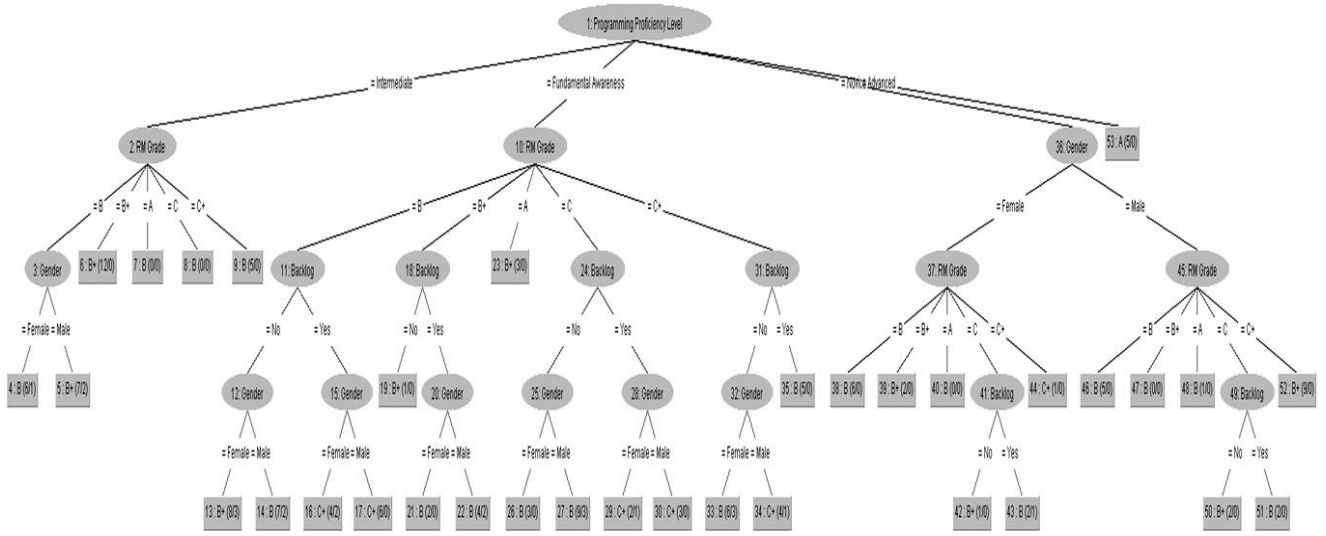

Fig. 2. The Constructed Random Tree Decision Tree using WEKA.

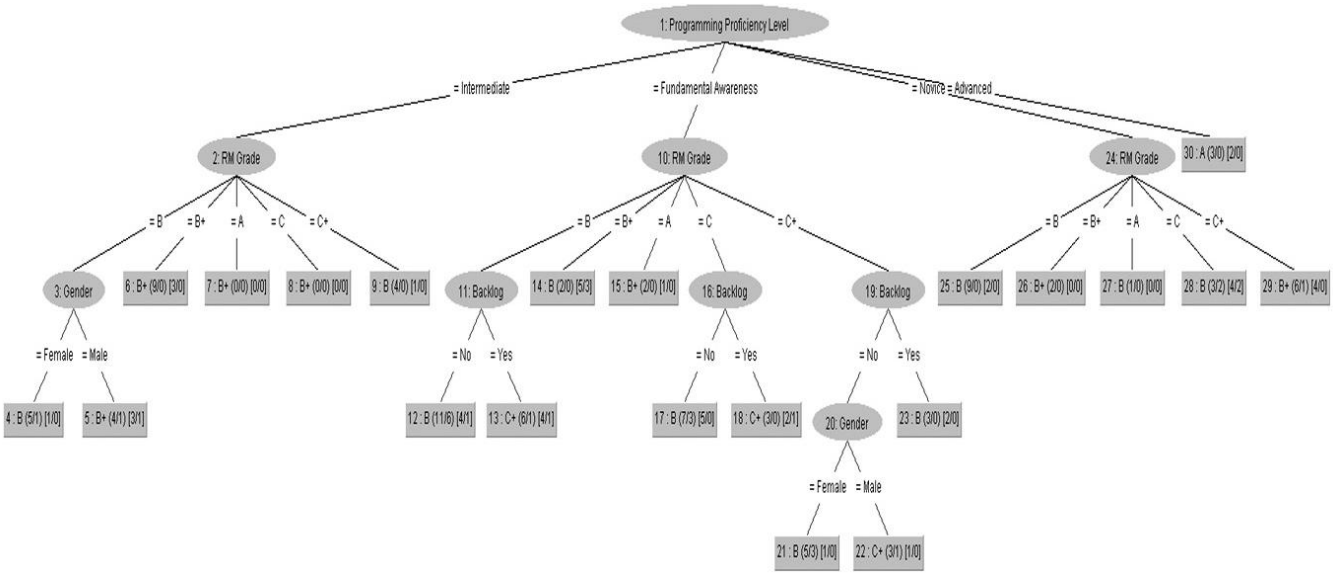

Fig. 3. The Constructed RepTree Decision Tree using WEKA.

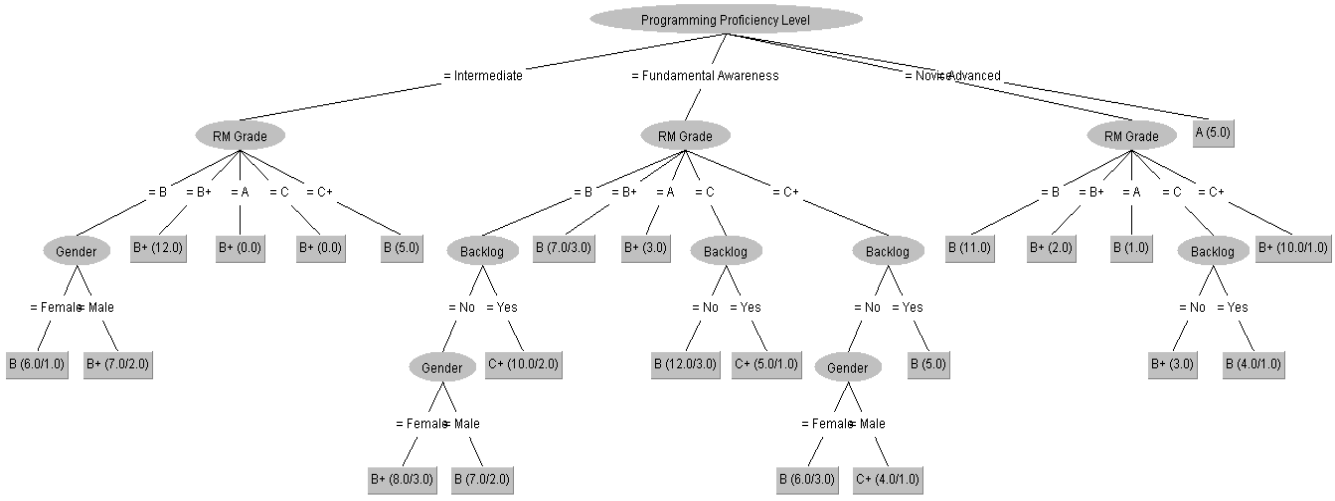

Fig. 4. The Constructed J48 Decision Tree using WEKA.

B. Classification Rules

Since Random Tree decision tree returned the highest accuracy after the 10-fold cross-validation, it was used to extract the classification rules. The rules were generated by getting the leaf nodes that were on the path of a root node in the decision tree. The logical conjunction of every leaf node from the path of a root node forms the rule while the root node represents the predicted grade.

A total of twenty-eight classification rules were extracted from the Random Tree decision tree as shown in Table III. The rules serve as a condition that when it is met, it would return an equivalent predicted grade. When the grade of a student is predicted, it can be used to determine if the student needs help in the research class.

C. RP Grade Predictor Software Application

Using the extracted classification rules from the generated decision tree, a Research Project Grade Predictor application shown in Fig. 5 was developed. The application was developed using the Visual C# programming language. Visual C# is one of the programming languages embedded in the Microsoft Visual Studio Express. The Microsoft Visual Studio Express is a collection free function-limited Integrated Development Environments (IDE) developed by Microsoft. The Visual C# IDE is a powerful and easy to use objected-oriented [20] programming language.

The software application was designed using a card base design to bridge the gap between interaction and usability [21] in a synchronized manner. It has a simple Graphical User Interface (GUI) that is user-centered wherein users are expected to run the application without training [22]. By using this application, the research instructor can now conduct proper counseling to students with low predicted grades.

TABLE III. THE SET OF CLASSIFICATION RULES

Rule No.	Rules	Predicted Grade	No. of Instances
1	If Programming Proficiency=Fundamental Awareness, RM Grade=A	B+	3/0
2	If Programming Proficiency=Fundamental Awareness, RM Grade=B+, Backlog=Yes, Gender=Male	B	4/2
3	If Programming Proficiency=Fundamental Awareness, RM Grade=B+, Backlog=Yes, Gender=Female	B	2/0
4	If Programming Proficiency=Fundamental Awareness, RM Grade=B+, Backlog=No	B+	1/0
5	If Programming Proficiency=Fundamental Awareness, RM Grade=B, Backlog=Yes, Gender=Male	C+	6/0
6	If Programming Proficiency=Fundamental Awareness, RM Grade=B, Backlog=Yes, Gender=Female	C+	4/2
7	If Programming Proficiency=Fundamental Awareness, RM Grade=B, Backlog=No, Gender=Male	B	7/2
8	If Programming Proficiency=Fundamental Awareness, RM Grade=B, Backlog=No, Gender=Female	B+	8/3
9	If Programming Proficiency=Fundamental Awareness, RM Grade=C+, Backlog=Yes	B	5/0
10	If Programming Proficiency=Fundamental Awareness, RM Grade=C+, Backlog=No, Gender=Male	C+	4/1
11	If Programming Proficiency=Fundamental Awareness, RM Grade=C+, Backlog=No, Gender=Female	B	6/3
12	If Programming Proficiency=Fundamental Awareness, RM Grade=C, Backlog=Yes, Gender=Male	C+	3/0
13	If Programming Proficiency=Fundamental Awareness, RM Grade=C, Backlog=Yes, Gender=Female	C+	2/1
14	If Programming Proficiency=Fundamental Awareness, RM Grade=C, Backlog=No, Gender=Male	B	9/3
15	If Programming Proficiency=Fundamental Awareness, RM Grade=C, Backlog=No, Gender=Female	B	3/0
16	If Programming Proficiency=Novice, Gender=Male, RM Grade=A	B	1/0
17	If Programming Proficiency=Novice, Gender=Male, RM Grade=B+	B	0/0
18	If Programming Proficiency=Novice, Gender=Male, RM Grade=B	B	5/0
19	If Programming Proficiency=Novice, Gender=Male, RM Grade=B	B	5/0
20	If Programming Proficiency=Novice, Gender=Male, RM Grade=C, Backlog=Yes	B	2/0
21	If Programming Proficiency=Novice, Gender=Male, RM Grade=C, Backlog=No	B+	2/0
22	If Programming Proficiency=Intermediate, RM Grade=A	B	0/0
23	If Programming Proficiency=Intermediate, RM Grade=B+	B+	12/0
24	If Programming Proficiency=Intermediate, RM Grade=B, Gender=Male	B+	7/2
25	If Programming Proficiency=Intermediate, RM Grade=B, Gender=Female	B	6/1
26	If Programming Proficiency=Intermediate, RM Grade=C+	B	5/0
27	If Programming Proficiency=Intermediate, RM Grade=C	B	0/0
28	If Programming Proficiency=Advanced	A	5/0

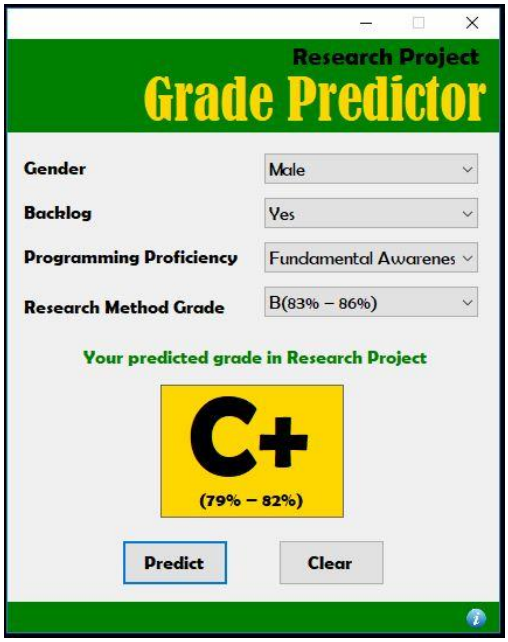

Fig. 5. The Grade Predictor Software.

IV. Conclusion

This study developed a classification model using a decision tree approach in predicting student grades in Research Project. It was limited to the use of only three decision algorithms which include Random Tree, RepTree and J48. The classification rules extracted from the Random Tree decision tree was used to create a software application that can be used by research instructors in identifying students who need academic counseling to improve their performance in research. The resulting accuracy of the classification model after the cross-validation means more samples and more attributes is still needed to arrive with a highly accurate prediction.

For future works, other decision tree algorithms should be used to analyze the data. The software application that can be developed with this kind of study can also be improved by adding a feature like allowing multiple student data to be analyzed at the same time.

Acknowledgment

I am thankful to God for giving me wisdom to finish this study. I am also thankful to the University of Saint Louis for all the help during the conduct of the research.

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A Review of Ontology Development Aspects

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***Abstract*—Although it is widely recognized that ontology is the main approach towards semantic interoperability among information systems and services, the understanding of ontology aspects among researchers is limited. To provide a clear insight to this problem and support researchers, we need a background understanding of various aspects related to ontology. Consequently, in this paper, a comprehensive review is conducted to map the literature studies to a coherent taxonomy. These include the benefits of ontology, types of ontology, application domains, development platforms, languages, tools, and methodologies. The paper also discusses the concept of ontology, semantic Web, and its contribution to several research fields such as Artificial Intelligence, Library Science and shared knowledge. The fundamentals of ontology presented in this paper can benefit readers who wish to embark in ontology-based research and applications development.**

Keywords*—Component; ontology; semantics web; artificial intelligence

I. INTRODUCTION

According to a book titled "Birth of a new science: the history of ontology from Suarez to Kant" [1], an Ontology is seen as an inter-discipline that involved two parts that are philosophy and science. Furthermore, the point of discipline is considered as the issue of foundations of science and not a discipline that exist separately. It is also considered as independent from other scientific discipline and branches of philosophy. Aside from science philosophy, the term is derived from general structure of the world [1]. To understand more, the structure of ontology is obtained from the knowledge that has been embodied into other disciplines. However, based on an article [2], it is said that ontology is the most comprehensive of all sciences that covers everything that exists from philosophy's perspectives. Similarly, it is also applied to information science's point of view with difference in essential definition ontology. Meanwhile from psychology's perspective, the ontology is uncommon to be used as the psychologists are more interested in studying on how people develop concepts and enhancing it from time to time.

Another article by N. Guarino, D. Oberle, and S. Staab [3] mentioned that ontology is mostly used with different meaning, depending on the communities that are utilizing the ontology. From a philosophy discipline, ontology deals with the nature and structure of "reality". Whereas in computer science discipline, it holds a unique kind of information of computational or object artifact as a mean to formal model of the system's structure; for example, a system able to become a company with all the employees and their relationship with one another.

As the term getting more known towards communities, various definitions were developed. The word ontology was taken from Philosophy, where it means a systematic explanation of being. In the last decade, the word ontology began used in artificial intelligence in the 1980s, and is now frequently used by computing and information science audiences. A few years later, Gruber [4] defined ontology as "an explicit specification of a conceptualization". This definition became the most quoted in literature and by the ontology community. One other definition is from Diana Man [5], he defined ontology as "consists set of concepts within a domain including the relationship between the concepts that considered as a formal representation of knowledge in computer science". Another article [6] defined ontology as "common vocabulary for researchers who are in need to share information in a domain".

The fundamentals of ontology presented in this paper can benefit readers who wish to embark in ontology-based research and applications development. It maps the current literature studies to a coherent taxonomy as shown in Fig. 1.

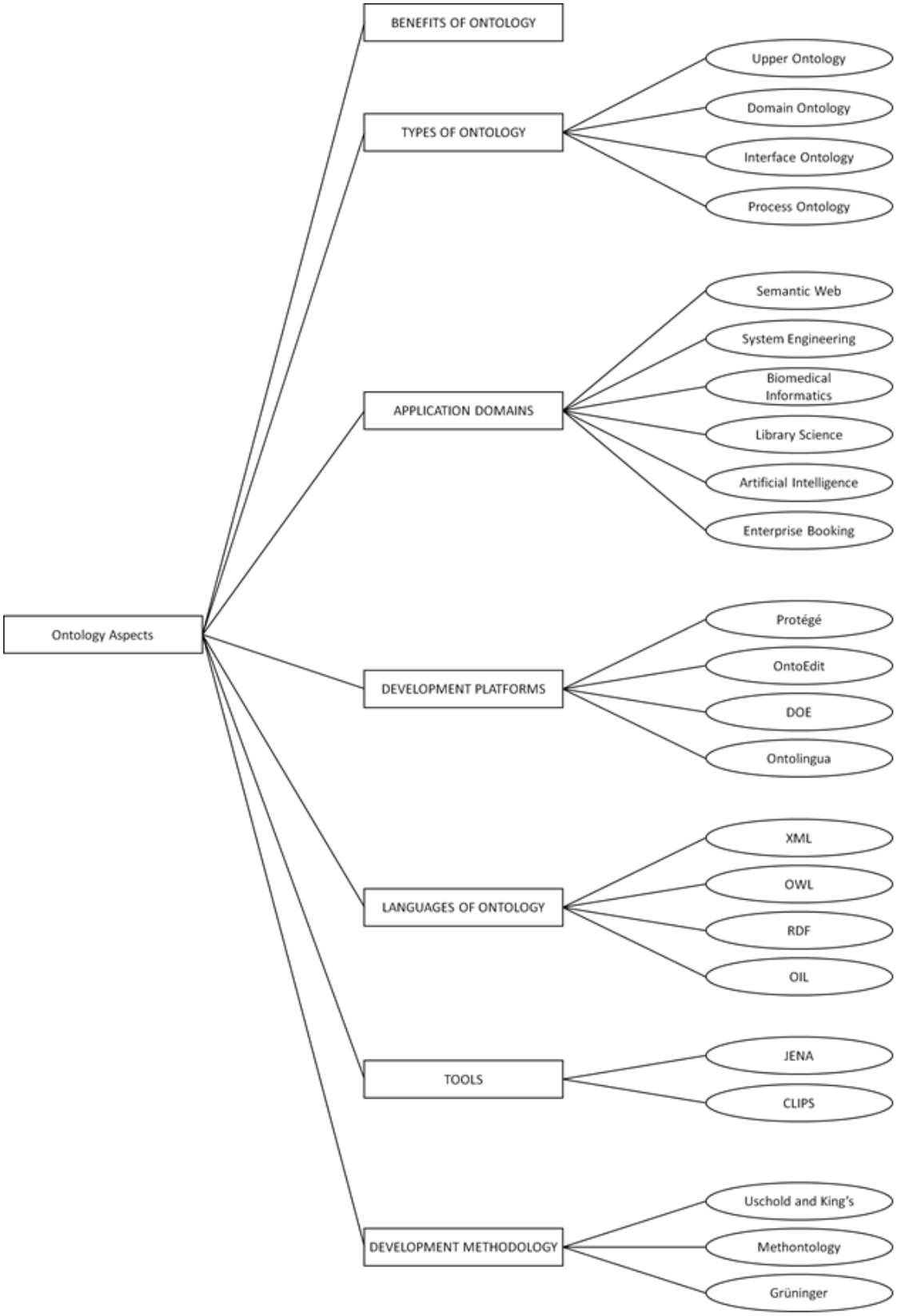

Fig. 1. The Taxonomy of Literature on Ontology Development Aspects.

II. Benefits of Ontology

One of the benefits is during the development of terminologies resources. Ontology could improve the content of built terminologies including its resources. According to Leonardi [7], the ambiguity of it able to be attributed to interdisciplinary and considered as most relevant way in expressing valuable resources in terminology aspect.

Author in [8] mentioned that ontology can assist in clarifying any structure of knowledge. The knowledge could be shared by using or through ontology that has been developed. To ensure the benefit is concrete, the author had done analysis by one satisfactory set of conceptualizations which includes respective terms from certain area of knowledge such as electronic-devices domain. In result, the ontology had captured specific knowledge bases by describing certain situation like various electronic devices manufacturers uses common vocabulary and syntax which product description's catalog was build.

According to [9], the features of ontology that is known to have essential relationship between concepts built into them are considered as its benefits. The feature enables the ontology to automate reasoning about data. In addition, it is easier to implement into semantic graph databases. The website also mentioned that ontology supports a variety of data representations such as unstructured, semi-structured or structured data which include better data integration, text-mining and data-driven analytics.

III. Types of Ontology

There are four types of ontologies, namely, Upper Ontology, Domain Ontology, Interface Ontology and Process Ontology [10].

Upper Ontology is an ontology defined as general concept to serve as common ground for communication specifically across different domains [12]. This raises questions of existing upper ontologies whether it could deal either as in part or as whole with social concepts. For example, "follower" in micro-blogging platform Twitter. Moreover, it consists of features like collaboration, federation and organization in a way to express the social policies and structures that could only be understood by others. [11] Nevertheless, upper ontology consists various types that are known as Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE), Basic Formal Ontology (BFO), General Formal Ontology (GFO), Yet Another More Advanced Top-level Ontology (YOMATO), Unified Foundational Ontology (UFO), PROTo Ontology (PROTON), Suggested Upper Merged Ontology (SUMO), Cyc and WordNet [13].

The second ontology is Domain Ontology. Unlike upper ontology, this ontology is a concept that belongs to a certain part of the world such as politics. Each domain ontology is modeled with specific definitions of terms [13]. Besides that, domain ontology consists of a collection of vocabularies and specifications of conceptualization of a given domain [14]. According to an article [15], the concepts and relationship between concepts within certain subject can be specified. The researcher emphasized that the model should closely be matched with the level of information found in a textbook of that subject.

Process Ontology is understood as a description of components and relationship that able to make up a process [13]. Moreover, this ontology known as specification of entities and its relationship that represents information including process and formal representation of domain processes. By this, it is able to incorporate a comprehensive and formal knowledge of an organization's processes, activities, roles, application systems and much more. Nevertheless, it requires the hand of time and effort to extract information like roles, documents and so on from unstructured text that contains any process information [17].

The last type of ontologies is known as Interface Ontology. It is an explicit statement of patterns that provide valuable opportunity on reflecting current methods. Besides, it utilizes the basic categories of physical existence that could explain any less understandable and experiences to ensure the ontology is able to do it. Physical metaphors are presented in a pattern form [18].

IV. Application Domains

Ontology consists of multiple types. Widely known is Semantic Web. Based on a research done by M.M. Taye [19], Semantic Web is a heterogeneous and distributed that brought the evolution of web into high level. Whereby the ontology plays an important role in semantic web. Another research [20] mentioned that semantic web is to enhance human and machine interaction by representing data in understandable way for machine to mediate data and services. Nonetheless, without the help of ontology, domain schemas could not be represented formally.

Another application is ontology in agent communication language (ACL) [51] [52] [53] [54] [55] [56]. Ontology is widely used in multi-agent communication protocol [57] [58] [59] [60]. It provides a concise description of exchanged messages between different agents [61] [62] [63] [64] [65].

Apart from that, System Engineering is an engineering discipline that responsible for creating and executing interdisciplinary processes to ensure stakeholders and customers are satisfied with the system throughout the system's life cycle [21]. Additionally, the role of ontology in system engineering is to become an intermediary between organizations and people by assisting them in the process of maintaining and building systems that could become as an inter-operability among systems. [22].

Another ontology application is Biomedical Informatics. It provides support of common vocabulary of biomedical concepts, definitions, relationships, axioms and rules that could control the knowledge flow into the knowledge base. [23]. Researcher Rishi Kanth Saripalle said that the ontology is used to partially solve data management issue in medical. Prior to that, GALEN ontology provides terminology for building blocks of terminology description also combination of concepts description. [23].

Ontology also plays a role in Library Science. In this regard, it supports easy accessibility and re-use of existing

ontologies [24]. Similarly with others, the ontology provides a formal conceptualization of data that able to be shared, aligned and reused in this application. As a result, a well-established and number of ontology development increases [25].

In Artificial Intelligence applications, the ontology helps to eliminate problems that are semantic and machine-understandable representation of knowledge. The ontology facilitates knowledge by reusing and sharing knowledge, thus becoming a potential solution. With that, it acts as a link between information and users through logical abstracting information. [26].

Finally, in Enterprise Booking ontology, according to [27], the ontology presents a dynamic engineering design process while it constantly evolves, a collaborative ontology engineering tools is expected.

V. Development Platforms

There are many platforms to support ontology design and development. One of those is Protégé. Protégé is an open source with free tool that supports huge community of active users. [29] Fig. 2 shows the interface of Protégé. Protégé provides an intuitive editor for ontology development with the help of tool extensions for ontology visualization, software engineering and other modelling tasks [30]. In addition, it provides a comprehensive Java-API to ensure it works with OWL and RDF models [31].

Meanwhile OntoEdit enables browsing, creating, maintaining and managing ontologies. However, a plugin architecture is required to be installed to ensure it is extensible and flexible for its purpose [29] With the plugin installed, OntoEdit not only ensure flexibility and extensibility but also able to export or import any ontologies that are in different formats such as RDF(s), XML and many more. The interface of OntoEdit is very similar to protégé, as shown in Fig. 3.

Although the interface layout is similar but the tools that are provided is different. While Protégé consists of "SQL Query" tab, "OntoGraf", "Classess" tab and so on, OntoEdit offers tabs that are nearly the same as Microsoft Words like fonts, size of fonts, color of fonts and much more [29].

Next is Differential Ontology Editor (DOE). The main advantage of this platoform is that it allows users to attach a lexical definition to relations, concepts, and justfiy the hiearchy. Despite having close name to OntoEdit, the interface of this platform is different as presented in Fig. 4.

The platform provides an import functionality. The ontology could be in form of XSLT, RDF(s), OIL, DAML+OIL and much more. This goes the same as the export function. DOE offers other features such as detection of cycles in hierarchices and ontology loading via URL [34].

Finally, Ontolingua is known to have a purpose of writing ontologies in canonical format. This is because it can be turned into a reasoning system with variety of representation. In addition to that, it allows one to maintain ontology into a machine-readable form while using different syntax and reasoning capabilities. Ontolingua is a public domain tool to define any common ontology. The syntax of ontolingua is based on standard notation and semantics for predicate calculus. With that, the platform is able to translate and implement into a representation systems and also captures common representational conventions such as inheritance hierarchies and inverse relation maintenance. Ontolingua enable renaming of non-logical symbols from multiple components of ontology. Thus, this platform supports cyclic graphs and extends ontologies in many ways [35, 36].

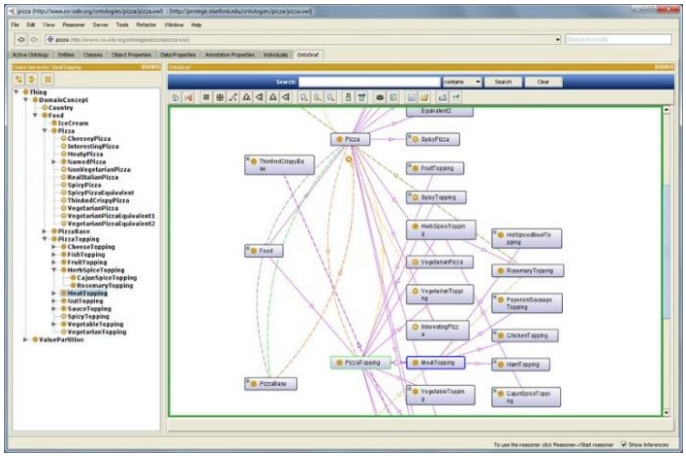

Fig. 2. Interface of Protégé [28].

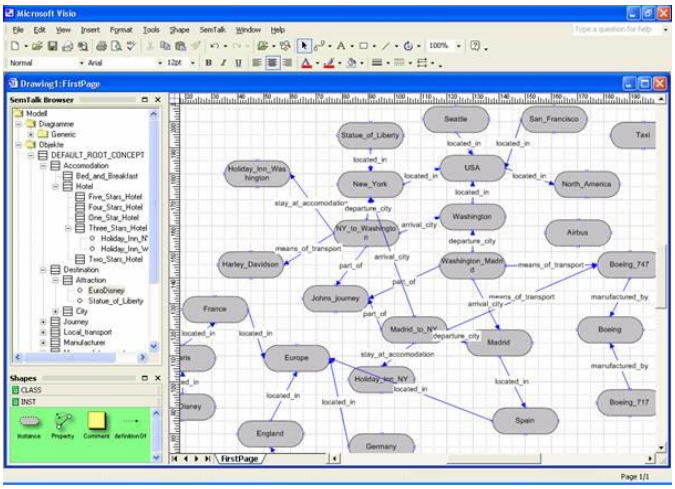

Fig. 3. Interface of OntoEdit[32].

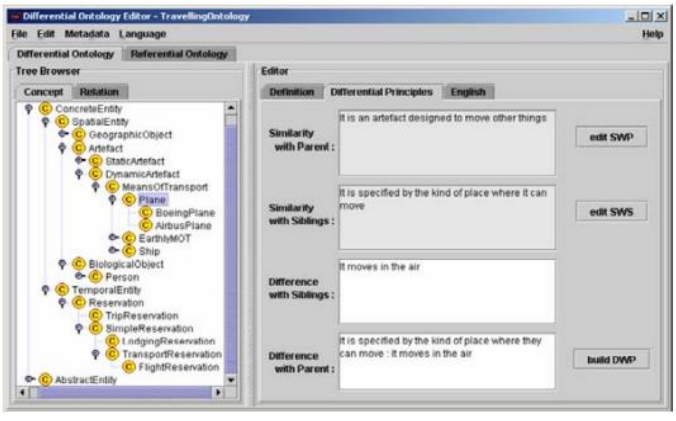

Fig. 4. Interface of DOE [33].

VI. Languages of Ontology

XML language is well-known. This language is a meta-language that facilitates the development of specialized tag languages. XML is strongly used in web specially to exchange data between applications [37]. Based on a study [37], the language was purposely designed to markup documents with arbitrary structures in opposed to HTML. The researcher also highlighted that this language creates a balance tree of nested sets of open and close tags. With that, each of the attribute value pairs without fixed vocabulary or set of permitted combinations can easily be defined. The syntax of this language is understandable by both platforms and human. Fig. 5 presents the syntax of the XML language.

The purpose of syntax is used to access the structure of documents. Any relevant information such as path expressions or templates for navigating are easier to locate within the document tree [38].

Next is Web Ontology Language (OWL). As mentioned by Techpedia, OWL was built upon standard with World Wide Web Consortium called Resource Description Framework (RDF) and have been evolved to many syntaxes and specifications. OWL has attracted great deals of interests from different fields such as medicine and academia [39]. This language was built on top of RDF and written XML. Based on a study, it is considered as part of the semantic web vision with the designed to be interpreted by computers. In result of the development, the purpose of OWL is to instantiate and define web ontologies with the description of properties, classes and instances of ontology [39] Although OWL is related to RDF and XML, the syntax or axioms however is entirely different than those two languages. Fig. 6 shows a sample of the OWL axioms.

```
WHERE
  <people>
    <person>
      <name>$P</name>
      <know-how>SGML</know-how>
    </person>
  </people> IN "some URL"
CONSTRUCT $P
```

Fig. 5. Illustration of XML Language Syntax

```
< owl : Class  rdf : about = "Author" / >

< owl : Class  rdf : about = "Paper" / >

< owl : ObjectProperty  rdf : about = "hasAuthor" / >

< owl : DatatypeProperty  rdf : about = "hasName" / >

< Author  rdf : about = "Bob" / >

< rdf : Descrition  rdf : about = "Bob" >
  < rdf : type  rdf : resource = "Author" / >
< /rdf : Description" >
```

Fig. 6. Axioms of OWL Language.

The basic OWL construction is axioms. Based on Fig. 5, the author explained that Axioms (1) and (2) is the Author and Paper concepts that are presented in OWL Class. Meanwhile, Axioms (3) and (4) stated that hasAuthor is an object property and hasName is a data property. While, Axioms (5) and (6) are two different methods to assert the individual Bob that is an instance of class Author [40].

Another popular language is Resource Description Framework Shema (RDF). According to the study [41], RDF offers a distinguished vocabulary to model class and property hierarchies and other basic schemas from RDF models. This language also defines and permits modelling of objects with clear definition of semantics. RDF is usually companied by RDFS language. Based on a study [42], RDFS is known as an extension for RDF that consists of ability to give vocabularies, taxonomies and ontologies. Although both were written in XML syntax and used in Protégé tool, there are few differences between these two languages. Table I shows the comparison of RDFS and RDF.

The similarities of these languages are class, data, objects, domain and range, annotation and individual properties. While the contrast of the languages is the inverse properties, RDF does not contain it but RDFS does. Moreover, RDFS is better in inferencing, indexing and searching. Finally, SPARQL query and DL query, RDF does not consist any of those two queries while RDFS has them [41].

Next is OIL language. This language is the production of OnTo-Knowledge plan. It can unify three crucial aspects. These aspects are Description Logic, frame-based system supplied modelling language and web standard based on syntax of XML and RDF(s). [42]. Prior to that, OIL was specially designed to present the exact machine-accessible semantics of information of the web [43]. The architecture of OIL language makes it unique compared to others. There are three architectures. First is Standard OIL, whereby it is aimed to capture important mainstream modelling primitives to ensure adequate expressive power. Second, is Instance OIL. This layer includes individual integration with a modelling that could construct and specify individual fillers in terms of definition. Last architecture, Heavy OIL includes additional representational and reasoning capabilities [44]. Fig. 7 shows a sample code of OIL language [45].

TABLE. I. Comparison between RDF and RDFS

Properties	RDFS	RDF
Class	Yes	Yes
Data	Yes	Yes
Object	Yes	Yes
Domain And Range	Yes	Yes
Annotation	Yes	No
Individual	Yes	Yes
Graph	RDFS	RDF
Inverse	Yes	No
Inference	Good	Poor
Indexing	Good	Poor
Searching	Good	Poor
SPARQL Query	Yes	No
DL Query	Yes	No
Prefix	RDFS	RDF

```
<rdfs:Class rdf:ID="herbivore">
  <rdf:type
      rdf:resource="http://www.
        ontoknowledge.org/oil/RDFS-
          schema/#DefinedClass" />
  <rdfs:subClassOf rdf:resource="#animal" />
  <rdfs:subClassOf>
      <oil:NOT>
          <oil:hasOperand rdf:resource="
            #carnivore" />
      </oil:NOT>
  </rdfs:subClassOf>
</rdfs:Class>
```

Fig. 7. Sample Code of OIL.

To elaborate, the OIL expression defines 'Herbivore' as a class and a subclass for 'Animal' and a disjunct to 'Carnivores'.

VII. Development Tools for Semantic Web

There are two well-known platforms for building Semantic Web. The first platform is JENA. It is a Java-based language platform with the purpose of creating applications for semantic web. This platform provides interfaces and classes for the manipulation and creation of RDF repositories. It also includes the capability of creating and manipulating RDF graphs. Furthermore, the semantic data can interact with the libraries contain inside JENA [46].

According to a study [47], JENA supports many description languages like DAML+OIL, RDFS, OWL and much more. Fig. 8 shows some part of the JENA codes that is used to create ontology.

GetStartedSemWeb.java

```
1 import java.io.IOException;
8 public class GetStartedSemWeb {
9 static String defaultNameSpace ="http://semanticweb.org/ontologies";
10 Model schema = null;
11    public static void main(String[] args) throws IOException
12    {
13    GetStartedSemWeb getsemweb = new GetStartedSemWeb();
14 System.out.println(" Adding  student ontology ");
15 getsemweb.loadontology();
16    }
17 private void loadontology() throws IOException{
18    schema = ModelFactory.createOntologyModel();
19        java.io.InputStream inschema = FileManager.get().open("C:/Users/AYESHA AMEEN/Desktop/docur
20    schema.read(inschema,defaultNameSpace);
21    ExtendedIterator it = ((OntModel) schema).listClasses();
22    while(it.hasNext())
23    {
24        OntClass cls= (OntClass)it.next();
25              System.out.println("URI of classes of Student Ontology are "+cls.getURI());
26
```

Fig. 8. Sample Code of JENA to Create Ontology.

```
(defclass <name>
   (is-a <superclass-name>+)
   (<slot>* <constraint>*)
   (<multislot>* <constraint>*))
```

Fig. 9. Basic Syntax for Defining Classes in COOL.

In Fig. 8, the codes consist of all necessary import to supporting Semantic Web applications. GetStartedSemWeb class is created for next default namespace and model. This class is to hold semantic data that have been declared while getsemweb in the main method. It is an object created and call made to loadontology method. Meanwhile, loadontology is another ontology created by calling ModelFactory. Create OntologyModel(). Aside from that they will call up another method to show the result of the ontology. JENA is not the only platform used for building Semantic Web, there is another one named 'CLIPS'. In an article explained that CLIPS is a RETE-based production rule engine that was written in C language. One interesting fact of this tool is that it able to integrate the production rule paradigm with OO model that can be defined by using COOL language (CLIPS Object-Oriented Language). CLIPS provide the necessary constructs to define classes with attributes and corresponding data model.

Fig. 9 shows the basic syntax of defining classes using COOL language. The attributes in COOL can take either a single value called slots or more than one value called multi slots. COOL regarded classes as type of objects and may also define it as attributes. Whereby, the classes of domain are usually organized in terms of class hierarchy by using subclass relationships that may have more than one direct super classes.

This tool is suitable for applications whereby ontologies are used as static models for sharing knowledge in heterogeneous environments. For example, the domain of Software Antipatterns [48].

VIII. Ontology Development Methodology

This section discusses three popular methodologies for ontology development. First is Uschold and King's methodology. This methodology has been developed based on Enterprise Ontology experience. Hence, able to provide guidelines for developing ontology [16]. Nevertheless, this methodology provides three phases for users to easily understand and follow the flow of a development process. Table II shows the summary of the three phases.

Meanwhile for Methontology, it was developed by an Ontological Engineering group at Universidad Politécnica de Madrid. Different with the previous methodology, Methontology enables the construction of ontologies at knowledge level which includes the root of the main activities that was identified by IEEE software development process and other knowledge engineering methodologies. Nevertheless, this methodology consists of six more steps than Uschold and King's methodology. All the steps are presented in Table III.

Methontology could identify management activities such as schedule, quality assurance, control and support activities [49]. Finally, this methodology also uses user-friendly approach in acquisition knowledge by non-knowledge engineer. This shows that the approach is an effective yet applicable method especially for domain-knowledge-model construction [50].

TABLE. II. SUMMARY OF THE PHASES USED IN USCHOLD AND KING METHODOLOGY

Phase	Summary
Identifying purpose	To clarify the reason why the ontology is built and what is the purpose of use of the ontology.
Ontology Capture	• To identify all the key concepts and relationships between a domain. • Precise unambiguous text definitions and identifying terms to refer to concepts and relationships in first phase.
Coding	Activities involved in explicitly representing knowledge
Integrating Existing Ontologies	Capture and coding process are involved and two questions are highlighted that is "how" and "whether" to use existing ontology
Evaluation	• Adopts the definition of making technical judgement of the ontologies and associate it with software environment and documentation
Documentation	All the guidelines of the ontology are established

TABLE. III. SUMMARY OF GRÜNINGER AND FOX METHODOLOGY

Steps	**Label**	**Summary**
1.	Capture of motivating scenarios	Development is mostly triggered by scenarios that tend to rise the application. Moreover, the scenarios are considered as examples of problems that didn't addressed adequately.
2.	Formulation of informal competency questions	All form of questions is based on previous scenarios and considered as expressiveness requirements. Most of the questions are stratified and can be used to answer general questions from another ontology.
3.	Specification of the terminology of the ontology	All informal terminologies are obtained. Whereby set of terms are extracted from the questions.
4.	Formulation of formal competency questions by using terminology	The competency of questions and the terminology of the ontology are formally defined
5.	Specification of definitions and axioms	Axioms and definition are arranged into a first-order sentences and are used to define the constraints and terms for the objects inside the ontology.
6.	Establish conditions for characterizing the completeness of the ontology	All questions and conditions have been formally stated and defined.

The third methodology is by Grüninger and Fox [16]. This methodology was created according to an experience of developing the TOVE project ontology. There are six steps in this methodology, as summarized in Table III.

IX. DISCUSSION AND RECOMMENDATION

Based on review, each of the ontology types has their own purpose. For example, domain ontology can be used to describe concepts, relationship, definitions with specific definition of a term. With that, domain ontology could assist any field such as Artificial Intelligence, Library Science, Biomedical Informatics and much more as these sectors are dealing a lot with definitions, terms and so on. However, for Upper Ontology, this particular serves as common ground for communication across different domains such as twitter or any organization that is required to communicate from different domains. Meanwhile, for process ontology is used to express the components and relationship that can make up as a process. With its capability to represent information of process and domain processes, an organization can apply this ontology to describe their role, processes, activities and much more of the organization. Nevertheless, to reflect any explicit patterns that could possibility provide valuable opportunity on current methods, it is best to use Interface Ontology as it uses basic categories of physical existence.

In order to develop the ontology, it is required to have a platform for development. As mentioned in this paper, there many tools that can be used to develop an ontology, though it depends on the developer's preference and needs. One of the most known platform among developers is protégé. As it is a free tool software included with tools extension to assist in visualization, software engineering and other modelling tasks. However, if a developer is requiring to manage or maintain an ontology, OntoEdit is the suitable platform to do so as it has the capability to manage and maintain but a plugin architecture is required to ensure the platform is flexible and extensible for the purpose. Another platform is Differential Ontology Editor (DOE), this tool can assist developers to create a lexical definition to relations, concepts, and justify the hierarchy. In addition to that, if developers need to import any ontology in any format, this tool can provide an import function for the purpose. Next, for ontology that is need to be written in a canonical format, Ontonlingua is the tool to use as it allows maintain an ontology into a machine-readable form by using reasoning capabilities and different syntaxes.

In connecting with the developing platform, there are also various languages that can be used by the developers, according to their preference. To facilitate data exchange between applications, common language to use is XML language. This language specialized in tag languages and also creates a balance tree of nested sets of close and open tags. With that users are not bound to define every attribute pairs with fixed vocabularies. Furthermore, another language that can be use is Web Ontology Language (OWL) with the combination of RDF and XML, users able to define and instantiate web ontologies by describing the instances, properties and classes of a particular ontology. Now, given that OWL is combination of RDF and XML, RDF can also be used as stand-alone. For RDF, the language able to define and allow

modelling objects with clear definition of semantics. Normally, when developers used this language, they will be accompanied by an extension that provide an ability to give taxonomies, ontologies and vocabularies called RDFS. Besides, this language can be used in Protégé software. If users are dealing with machine-accessible semantics information of the web, the language that has the functionality to do so is OIL language. Unlike the other languages, OIL consist three architecture known as Standard OIL, Instance OIL and Heavy OIL. Each of the architecture has their own role in this language to carry out the task.

In any case if the developer is interested to build an ontology in semantic web, there are two softwares can be used. One is a Java-based platform known as JENA that can handle multiple description language (ie: RDFS, OWL etc). Second is CLIPS, a C-language tool that able to integrate a production rule paradigm with COOL language suitable for static model ontology in sharing knowledge in a heterogeneous environment. As we known that ontology is a development process.

Therefore, to assist developers in building ontology, there are three methodologies to use. The common methodology is Uschold and King's methodology that provide a guideline of each phases in developing ontology. In comparison with Methontology, this method able to identify management activities and it is said to be an effective yet applicable approach for domain-knowledge model construction. Lastly, similar to both methodologies, the Grüninger and Fox Methodology was created based on the experience of TOVE project ontology that has six steps, begin with capturing motives and ending with established condition. To conclude, ontology can be developed through various ways according to the suitability and preference of a certain project and developers. Unlike any other development projects, ontology is dynamic and flexible that is not bound to a certain development process or progress to be created.

X. Conclusion

An overview of the ontology development aspects has been presented in this paper. The definition of ontology was discussed from different perspectives. Additionally, various types of ontology are available to be known as Upper Ontology, Domain Ontology, Interface Ontology and Process Ontology was mentioned. Moreover, all types of ontology discussed have applied in various domain such as Semantic Web, System Engineering and Biomedical Informatics. Furthermore, three common development platform and designing ontology which are Protégé, OntoEdit, Differential Ontology Editor (DOE) and Ontolingua are also presented in this paper. Besides that, basic languages are also discussed. Finally, from various development tools to languages, both are used together to build an ontology by several methods which are Methontology, Uschold and King's and Gruninger and Fox.

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Post Treatment of Guided Wave by using Wavelet Transform in the Presence of a Defect on Surface

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***Abstract*—This article presents a Lamb wave processing by using two methods: Fast Fourier Transform (FFT2D) and Continuous Wavelet Transform (CWT) using Morlet wavelet. This treatment is done for a structure of two aluminum-copper plates, which are in contact edge to edge of a perpendicular junction with a thickness "e" in the presence of a rectangular and symmetrical defect located on the surface of the junction with a depth "d". The aim under this study is to calculate the transmission and reflection energy coefficients by the two methods. The results of simulation obtained by Comsol software of an incident wave S_0 at F = 800 kHz indicate us a good coherence between the two methods (FFT2D and CWT).**

Keywords*—Lamb wave; defect; reflection; transmission; CWT; FFT2D

I. INTRODUCTION

Lamb [1] presents dispersion's equation of Lamb waves that propagate in an elastic plate. This discovery would lead to many applications in different areas such as non-destructive testing. Recently, Viktorov [2] will devote a large part of his work to these waves called Lamb waves. Among the advantages of these waves, we find their propagation over a long distance that can attain a few hundred meters depending on the configuration of the structure and the frequency of the transducers used.

The relationship between the time and the displacements is obtained using the resolution of wave Lamb propagation equations.

These displacements are treated by FFT in order to extract dispersion's curves and to convert incident wave into transmitted and reflected waves. Recently, we remark a significant use of wavelet transformation in domain of non-destructive control.

Wavelet analysis was introduced in the early 1980, it gives a representation of the signals allowing the simultaneous enhancement of the temporal and frequency information (time-frequency localization). Thus the need for wavelets, a family of functions deduced from the same function (called mother wavelets) by translation and dilation operation, was felt by noting that the Fourier transform which dominated from the beginning of 19th century, lost during the projection the control of the temporal variable during the projection and is still unable to describe locally (in time or space) the frequency behavior of the signals.

Pablo R Souza and Euripedes G O Nobrega [3] presented a method for locating and assessing the severity of damages in aluminum plates using a Lamb wave approach through a circular array of sensors and a centered actuator.

Xin Zhang et al [4] presented an experimental study on the simulated acoustic emission sources with different propagation distances, types and defect for rail defect detection. Sergio Cantero-Chinchilla et al [5] presented SHM methods for damage detection and localization in plate-like structures relied on signal post-processing techniques applied to ultrasonic guided waves. Fei Gao et al [6] are used the Time of flight based method and the continuous wavelet transform in order to localize the damage in composites laminates.

Kaihong Zheng et al [7] proposed a non-destructive testing and evaluation (NDE) method based on Lamb waves in order to detect damage in stiffened composite panels. Jinrui Zhang et al [8] are employed the CWT to analyze the Lamb wave dispersion of the detected signal. Bo Feng et al [9] are presented a method that is able to detect and assess delamination's length in anisotropic CFRP plates using chirp-excited Lamb wave and wavelet analysis. Faeez A. Masurkara and Nitesh P. Yelveb [10] are carried out on an aluminum plate with and without damage using Lamb wave in order to locate single as well as multiple damage based on wavelet transform algorithm. Michele Carboni et al [11] are studied the propagation of Lamb wave for quasi-isotropic CFRP laminate with the aim to set-up a "single propagation mode" approach. Guoqi Zhao et al [12] are used ultrasonic guided wave in order to detect the delamination of composite double cantilever beams (DCBs). The study of Zhongqing Su et al [13, 14] based on a Lamb wave propagation-based delamination identification scheme for CF/EP composite structures [13] to detect delamination in the structures. Then they are focused on their study to provide a comprehensive on the Lamb wave-based damage identification approaches for composites structures [14].

Among the treatment that used FFT we find, Taoufiq Belhoussine Drissi et al [15] that studied the reflection and the transmission of guided wave at the right junction of two different elastic plates with the presence of a defect, and Mouna Seddiki, Hakim Djelouah [16] which their study focus on the identification of propagative Lamb mode in a plate with the presence of a defect.

For the treatment used by WT we find, Beata Zima and Magdalena Rucka [17] that presented an experimental study of guided wave propagation on a steel plate with an internal defect by using continuous wavelet processing to obtain accurate reconstruction of reflected waves, and a study proposed by D. Waltisberg, R. Raišutis [18] based on the separation of the first symmetric mode S_0 and the first asymmetric mode A_0 and the reliable estimation of their group velocities by using tree methods among them the wavelet transform. LeiYangI. CharlesUme [19] are used CWT for a thin steel plate in order to calculate the transmission coefficients of laser-generated Lamb waves. Taoufiq Belhoussine Drissi et al [20] are used the wavelet transform for a speech signal in order to determine the choice of the appropriate wavelet analyzer with the method of extraction of MFCC coefficients for an assistance in the diagnosis of Parkinson's disease. Tsun-Yen Wu [21] et al are used the CWT to help identify wave packets of the S_0 and A_0 Lamb wave modes in order to detect defects in thin structures. Lei Yang, I et al [22] are used the LEU technique to inspect the notch depths in thin steel plates and by the CWT they computed the transmission coefficient of Laser generated Lamb wave.

Another research used both the FFT and CWT, among them M. Sifuzzaman [23] that compared analytically the advantages of the wavelet transform according to the Fourier transform and also Mhammed El Allami and Hassan Rhimini [24] that used the wavelet transformation to determine the energies of the different Lamb modes propagating in a steel plate with an internal, rectangular and symmetrical defect with respect to the axis of propagation.

In the present work, we come up with a treatment by the continuous wavelet and Fourier transform (CWT and FFT2D) for two isotropic and thin plates aluminum-copper which are connected to each other by a perpendicular junction with the presence of a rectangular and symmetrical defect on the surface of the junction. The objective of this treatment is to calculate the reflection and transmission energy coefficients, then compare the results obtained by the two methods (FFT2D and CWT).

II. Presentation of the Studied Structure

For this treatment, we use the structure below:

The structure contains two isotropic and thin plates aluminum-copper which are in contact edge to edge with thickness e = 2mm in the presence of a rectangular defect with depth d and located symmetrically on the median plan.

Aluminum is indicated by index 1 and characterized by the density ρ_1, a longitudinal c_{l1} and transversal velocity c_{t1}. Copper is indicated by index 2 and characterized by the density ρ_2, a longitudinal c_{l2} and transversal velocity c_{t2}.

The table below presents the characteristics of aluminum and copper plates:

TABLE. I. Characteristics of Aluminum and Copper plates

Characteristics	Aluminum	Copper
Density (kg/m^3)	2799	8705
Transversal velocity (m/s)	3115	2360
Longitudinal velocity (m/s)	6320	4728

III. Numerical Study

The study is done by Comsol software, the structure used in Finite Element Method (FEM) is identical to Fig. 1.

The incident mode S_0 is emitted from aluminum plate with frequency F = 800 kHz. Each plate has a length of 100mm with thickness e = 2mm.

The processing is done with the aim of studying the reflection and the transmission of Lamb wave through the junction by FFT2D and CWT.

The studied junction is situated at x = 100mm, the following Fig. 2 indicate us the presence of incident and reflected wave between 0 and 100mm and transmitted wave for a value more than 100mm.

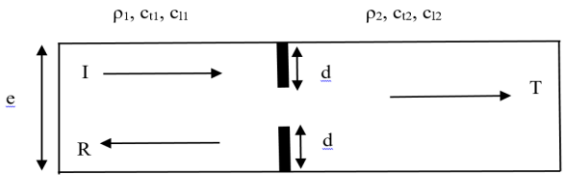

Fig. 1. Structure of Aluminum-Copper Plates with a Defect.

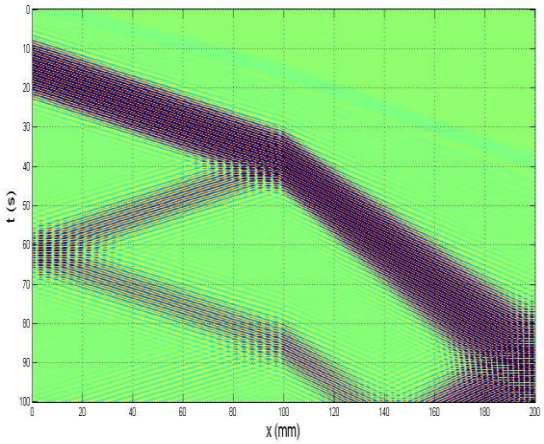

Fig. 2. Time-Position Image of Displacements (F = 800 kHz).

IV. Treatment by FFT2D Method

From the time-position signal, we calculate the temporal Fourier transform of the signal s(x, t), we obtained a signal called φ(x, F) for a fixed position. For each frequency F, we apply a second Fourier transform and we obtained the signal ψ(K, F) (Fig. 1). This signal resulting from this double Fourier Transform is located in the dual frequency-wavenumber space. See Fig. 4 (ψ(K>0, F) incident wave, ψ(k<0, F) reflected wave) and Fig 6 (ψ(K>0, F) transmitted wave) [25].

To identify different modes presented in the simulated structure, we superpose the theoretical dispersion curves on the numerical study.

Then we cut the signal resulting from the double Fourier transform at the frequency F = 800 kHz to obtain the magnitudes of each mode as shown in Fig. 5 and Fig. 7.

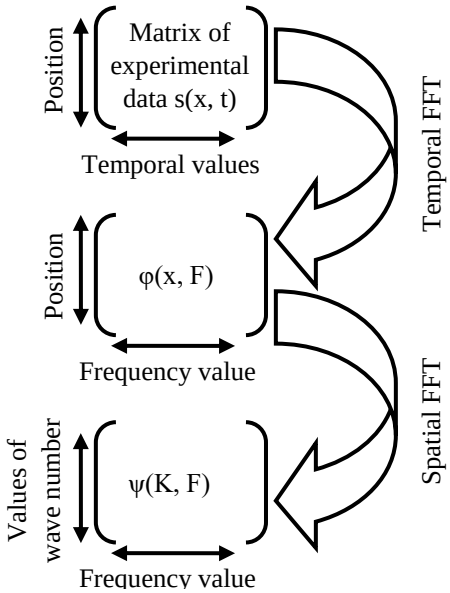

Fig. 3. Signal Processing Applied Spatial and Temporal FFT.

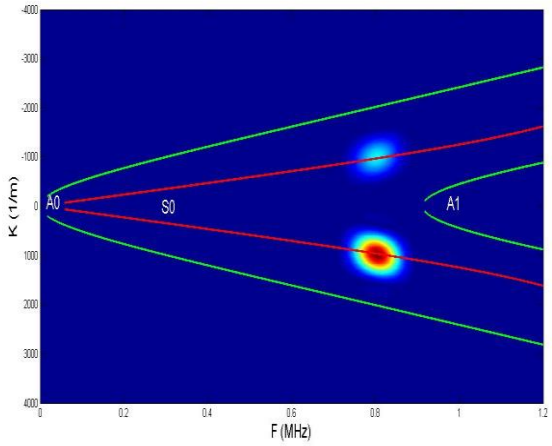

Fig. 4. Representation Frequency–Wave Number for Aluminum Plate.

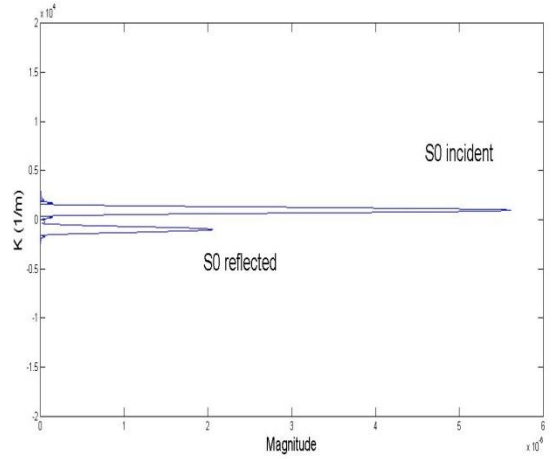

Fig. 5. The Magnitude of the Transmitted Mode.

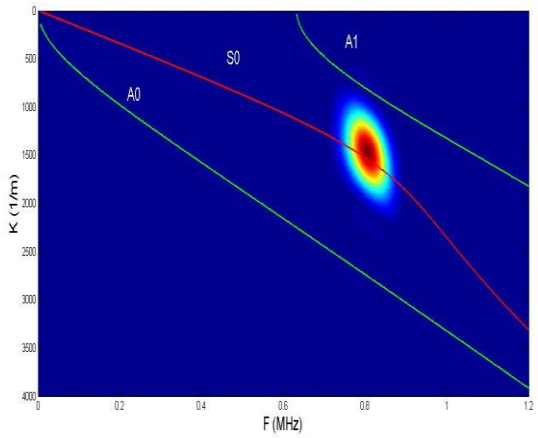

Fig. 6. Representation Frequency–Wave Number for Copper Plate.

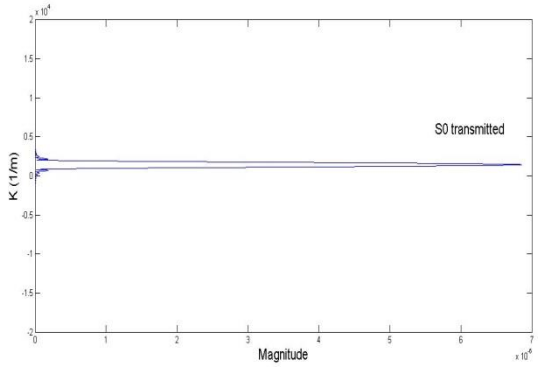

Fig. 7. The Magnitude of the Transmitted Mode.

The distribution of the energy of the incident mode between the reflected and transmitted mode is done by calculating the magnitude of each mode.

The superposition of the theoretical dispersion curves on those obtained by FFT2D show us that at the frequency F = 800 kHz, we have just the symmetrical mode S_0 while the junction is symmetrical.

V. Treatment by the Wavelet Transform Method

The CWT has been developed to overcome some resolution defaults of the Fourier Transform. It is able to provide a simultaneous time-frequency representation of the signal. In 1982, Morlet [26] opened the way to the solution by building the wavelet transform.

The continuous wavelet transform uses two parameters: one called the scale of the wavelet "a", it can give different version of wavelets by compressing, and dilating the same mother wavelet, it presents the inverse of the frequency. The other is the translation parameter "b" which translates the wavelet along the time axis of the signal. The continuous wavelet transform of a signal s(t) is defined by:

$$W(a,b) = \int_{-\infty}^{+\infty} \psi^*\left(\frac{t-b}{a}\right) s(t)\,dt \qquad (1)$$

Where: Ψ(t) is the wavelet function, Ψ*(t) is Ψ(t) complex conjugate, W(a,b) are the continuous WT coefficients.

We apply the continuous wavelet transform by using the mother wavelet Morlet for displacements collected at points situated before the defect (x = 40mm) and after the defect (x = 110mm) in order to obtain the 3D plot of wavelet coefficients. See Fig. 8 and Fig. 9.

In general, the maximum wavelet coefficient depends on the shape of the wavelet: when the section of the signal has the same shape as the wavelet, we obtain the maximum value of the wavelet coefficients.

In our case, we confirm that a = 10 corresponding to the maximum value of coefficients wavelet as shown in Fig. 10 and Fig. 11, then the row of the coefficient matrix for this scale was plotted as function of time. See Fig. 12 and Fig. 13.

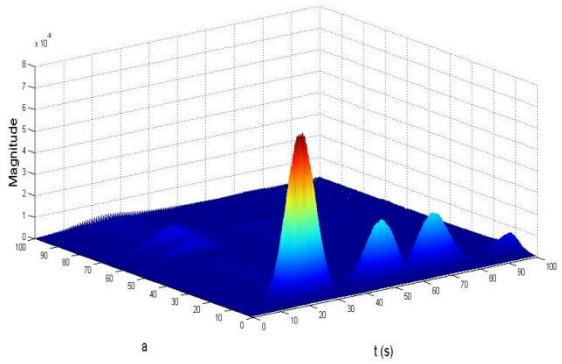

Fig. 8. Wavelet Coefficients for Displacements before the Defect.

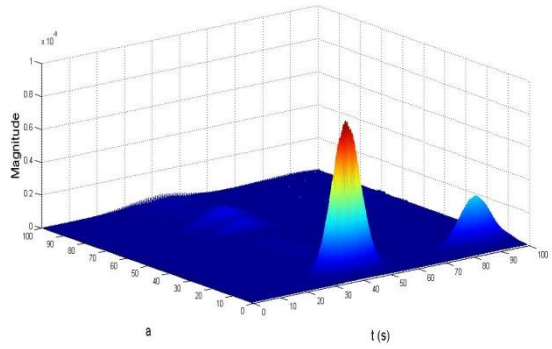

Fig. 9. Wavelet Coefficients for Displacements after the Defect.

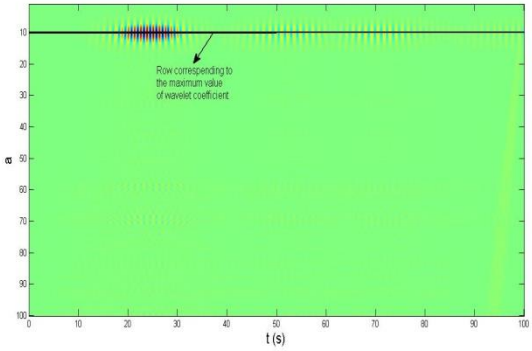

Fig. 10. Time-Scale Representation of Wavelet Coefficients for the Displacements before the Defect at F = 800 kHz.

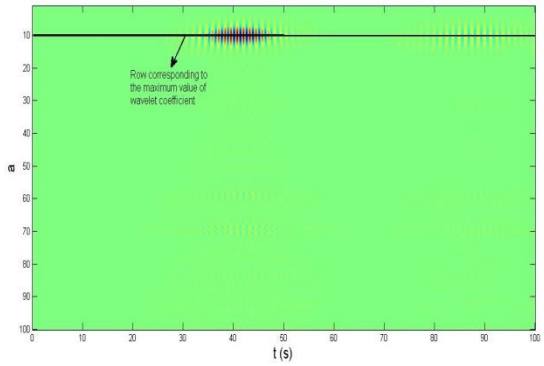

Fig. 11. Time-Scale Representation of Wavelet Coefficients for the Displacements after the Defect at F = 800 kHz.

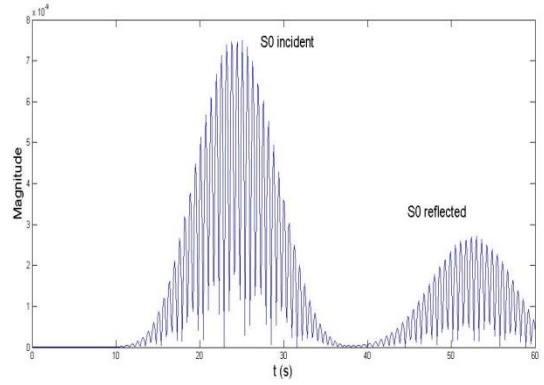

Fig. 12. Wavelet Coefficients for the Displacements: before the Defect at F = 800 kHz.

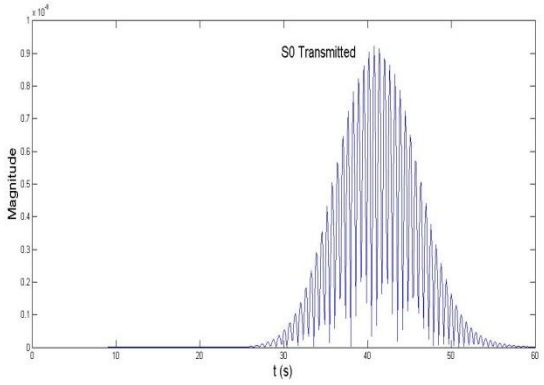

Fig. 13. Wavelet Coefficients for the Displacements after the Defect at F = 800 kHz.

After the determination of the magnitudes of incident, reflected and transmitted mode for each method (Fig. 5, Fig. 7 for the FFT2D and Fig. 12, Fig. 13 for CWT), now we can deduce the reflection and transmission energy coefficients by applying the following equations [15, 24].

$$R(S_i) = \frac{\left(A^R(S_i) * \zeta^I(S_0)\right)^2}{\left(A^I(S_0) * \zeta^R(S_i)\right)^2} \quad (2)$$

$$T(S_i) = \frac{\left(A^T(S_i) * \zeta^I(S_0)\right)^2}{\left(A^I(S_0) * \zeta^T(S_i)\right)^2} \quad (3)$$

Where: A^I, A^R and A^T are the magnitudes of the modes where the higher index present respectively incident, reflected and transmitted mode. The coefficients ζ are defined by the module of the normal displacement on the surface of the plate divided by the square root of Poynting vector [11].

$$\zeta = \frac{\left| U_z\left(z = \pm\frac{e}{2}\right)\right|}{\sqrt{\phi}} \quad (4)$$

VI. Results of the Two Processing

The transmission and reflection energy coefficients obtained by the two methods (FFT2D and CWT) in the case of the incident mode is the symmetrical mode S0 at frequency F= 800kHz in the presence of a defect, where the report of the depth of defect by the thickness of the plate is (d/e = 1%, 2%, 3%, 4% and 5%) are presented in the following Fig. 14:

The continuous curve in blue indicate the reflection energy coefficient obtained by FFT2D and the curve with stars is the reflection energy coefficient obtained by CWT.

The continuous curve in red indicate the transmission energy coefficient obtained by FFT2D and the curve with stars is the reflection energy coefficient obtained by CWT.

The continuous curve in black indicate the energy conservation R+T obtained by FFT2d and the curve with stars is the energy conservation obtained by CWT.

This figure indicates that the results of the two methods in presence of a defect with (d/e = 1%, 2%, 3%, 4% and 5%) are identical with a neglected error, and an energy conservation R+T ≈ 1. We can deduce that there is a good coherence between FFT2D and CWT and when the report d/e increase the reflection energy coefficient increase and the transmission energy coefficient decrease.

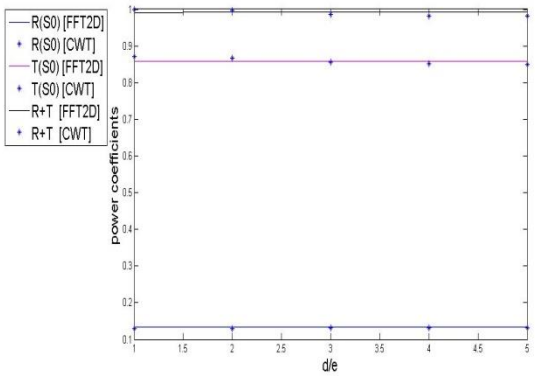

Fig. 14. Transmission and Reflection Energy Coefficients and Energy Conservation.

VII. Conclusion

In this paper, we proposed a treatment of Lamb wave for a two aluminum-copper plates, which are in contact edge to edge by a perpendicular junction with an internal, rectangular and symmetrical defect. This processing is done by two methods: the Continuous Wavelet Transform (CWT) and the Fast Fourier Transform (FFT2D) in order to calculate the reflection and transmission energy coefficients. The obtained results showed us a good coherence between the two methods (FFT2D and CWT). By increasing the thickness of the defect, the reflection energy coefficient increased and the transmission energy coefficient decreased. As prospect, we can use other mother wavelet such us Coifman, Daubechies etc.

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Vectorization of Text Documents for Identifying Unifiable News Articles

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***Abstract*—Vectorization is imperative for processing textual data in natural language processing applications. Vectorization enables the machines to understand the textual contents by converting them into meaningful numerical representations. The proposed work targets at identifying unifiable news articles for performing multi-document summarization. A framework is introduced for identification of news articles related to top trending topics/hashtags and multi-document summarization of unifiable news articles based on the trending topics, for capturing opinion diversity on those topics. Text clustering is applied to the corpus of news articles related to each trending topic to obtain smaller unifiable groups. The effectiveness of various text vectorization methods, namely the bag of word representations with *tf-idf* scores, word embeddings, and document embeddings are investigated for clustering news articles using the k-means. The paper presents the comparative analysis of different vectorization methods obtained on documents from DUC 2004 benchmark dataset in terms of purity.**

***Keywords*—Vectorization; news articles; tf-idf; word embeddings; document embeddings; text clustering**

I. Introduction

Recent developments in the world wide web have paved way for sharing different forms of information seamlessly on any platform. Among all the various sources of data, the textual representation of data continues to be the most widely used for communication and hence attracts the attention of the researchers to focus on developing automated tools for understanding as well as synthesizing textual information.

In this era of information outflow where billions of bytes of information are being created and shared worldwide for various purposes, it is essential to use the computing power of the machines for uncovering the unseen insights by transforming data to the way the machine understands. The realm of natural language processing has many possibilities for further research in making the interactions between human and machines much transparent. The initial step towards making the text documents machine-readable is vectorization.

Transforming textual data to meaningful vectors is a way to communicate with the machines for performing any Natural Language Processing tasks and solve problems mathematically. Researchers in the domain had proposed different vectorization models that range from a very simple to sophisticated ways helpful in solving NLP problems. A straightforward but ineffective way to build the vectorization table is, mapping all the words in the vocabulary to some integer value.

The work presented in the paper focusses on studying the impact of different vectorization methods for clustering text documents using the k-means algorithm. It is part of a framework which collects news articles based on URLs mentioned in social media posts, clusters the articles into smaller unifiable groups and automatically summarizes the multiple articles of each group for preparing a comprehensive news story related to the most trending topics and capturing the opinion diversity for the topics.

The organization if the paper is as follows, Section II presents the Related Literature, Section III introduces the framework for Identification and Hybrid Summarization of Unifiable News Articles. In Section IV, the paper details various Vectorization methods studied for the work; Section V briefs the Unifiable News Articles Identification process using Text Clustering with k-means. Section VI gives the details of the Dataset, Experimentation, Evaluation and Results. Section VII presents the Conclusions and Future Work.

II. Related Literature

A brief introduction to the prevailing text vectorization methods and contemporary word embedding models is as follows.

TF-IDF: Term Frequency-Inverse Document Frequency [1] is the most commonly used method in NLP for converting text documents into matrix representation of vectors. Tf-idf representation reflects the prominence a word in a collection of documents to the individual document. Successful search engines could be developed based on the potential of tf-idf scores for representing the prominence of words in the text to capture the relevance of the document to a given search query. However, the Inverse Document Frequency (idf) score calculation is vocabulary specific and hence hinders the applicability of tf-idf scores for dynamically changing corpora.

GloVe: Is a count-based model which constructs a global co-occurrence matrix where each row of the matrix is a word while each column represents the contexts in which the word can appear. The GloVe [2] scores represent the frequency of co-occurrence of a word with other words. GloVe learns its vectors after calculating the co-occurrences using dimensionality reduction. Other benefits of GloVe are its parallelizable implementation and ease of training over the large corpus.

Deep learning techniques were applied to process enormously large collections of text to extract word embeddings without confining to specific vocabulary or

corpora. Hence, word embedding has become the better choice for converting the text to machine-readable vectors for a wider variety of applications, including document summarization, language translation, question answering, and others.

Word embedding is a collection of different language modelling and feature learning techniques in NLP domain. The words or phrases in the vocabulary are mapped to vectors of real numbers, usually to a high-dimensional representation of words based on the context in which they appear.

Word2Vec: Word2Vec [3] builds a distributed semantic representation of words in the document. The model could be trained in the context of each word, such that similar words have similar numerical representations. Word2Vec is a predictive model that learn its vectors for reducing their loss of predicting the target words, from the given context words.

SentenceToVec: SentenceToVec is an extension to Word2Vec representation where feature representations at sentence level or the complete document are learned instead of words, by averaging the vector representations of all words in the sentence. Skip-Thought Vectors [4] released in 2015 have made good progress in sentence-level embeddings.

Doc2Vec: Doc2Vec [5] is an extension of Word2Vec or rather SentenceToVec as sentences are a part of documents, and the procedure of obtaining the Doc2Vec embeddings is similar to that of SentenceToVec.

While the single-level word embeddings discussed above are undoubtedly the most used of the word embeddings, they are still limited to capturing only the syntactic and semantic information of words from the sizeable collection of unlabeled text. While these methods suffice for document clustering, they cannot effectively handle more complex NLP tasks like Question-Answering, Textual Entailment, Named Entity Resolution, Sentiment Analysis and other as they produce context-independent embeddings with limited capability for Word Sense Disambiguation (WSD).

ELMo and BERT are the recent advancements for generating context-dependent word embeddings at multiple levels to be incorporated into various layers of deep learning models for solving complex NLP tasks successfully. Context-dependent embeddings like ELMo and Language Understanding models like BERT have taken the field to a different level.

ELMo: Embedding from Language Model (ELMo) [6] is a bidirectional Language Model (biLM) whose vectors are pre-trained using a large corpus to extract multi-layered word embeddings. ELMo Learns conceptualized word representations that capture the Syntax, Semantics and Word Sense Disambiguation (WSD). ELMo could be coupled with existing deep learning approaches for building supervisory models for a diverse range of complex NLP tasks to improve their performance significantly.

BERT: Bidirectional Encoder Representations from Transformers (BERT) [7] is based on the bidirectional idea of ELMo but uses a Transformer [8] architecture. BERT is Pre-trained to learn bidirectional representations by jointly conditioning the contexts of the corpus in both directions for all the layers. The pre-trained vectors could be used in complex NLP tasks and can achieve state-of-the-art results with only one additional layer at the output.

III. Framework for Identification and Hybrid Summarization of Unifiable News Articles

The proposed framework for Identification and Hybrid Summarization of Unifiable News Articles collects its inputs from a popular website, Trends24, which publishes the trending topics from Twitter on an hourly basis. Trends24 publishes real-time twitter trends in the form of hashtags and topics at multiple levels of granularity worldwide or in certain countries or cities. It has got a development page where the trending hashtags and topics of the entire day in a 24-hour frame is available. This page helps us to easily scrape the contents and extract all the information required for further processing. Figure 1 depicts the different phases in the framework.

After scraping the trending topics from trends 24, one can choose any of the popular and trending topics of interest based on how long it has been in the top trends. The trending hashtags or topics identified in the first part of the framework are used to gather all the tweets associated with those topics/hashtags. Twitter allows access to their data using APIs after establishing proper authentication using OAuth. OAuth is a standard for access delegation; it is used by websites or applications to access information from other websites without having to reveal any of the access credentials [9]. Twitter APIs like the Search API, Streaming API, and the REST API can help us obtain the publicly available data for free. Apart from these, there are other ways in which you can get more substantial chunks of data for real-time applications. Most of the popular programming languages provide built-in libraries for collecting and analyzing the tweets. A plethora of third-party tools is available on the web for performing various levels of analytics using social media [10].

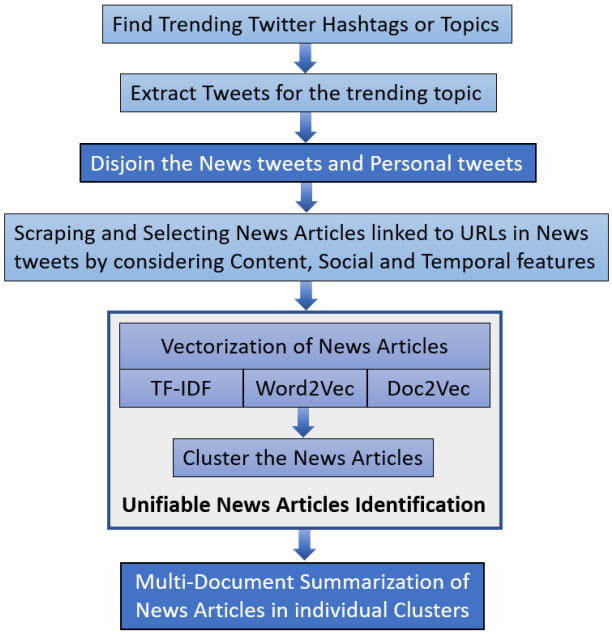

Fig. 1. Identification and Hybrid Summarization of Unifiable News Articles.

After obtaining enough number of tweets for a given topic, the next step in the framework is to separate and filter the News tweets from the collection. The method for identifying the news tweets from the collection works in three steps. In the first step, the *screenNames*(pseudonyms) are correlated with a set of news specific patterns to isolate the news tweets. The second step looks for news-related keywords by matching the tweet *tex*t with an extensive collection of news words to generate another partial set of tweets. Tweets extracted from both the streams are merged, followed by removing all duplicates, from this combined set, tweets only of the form *<TEXT, URL>* without any profanity words in the tweet text are selected to form the final set of news tweets. The details of the methodology for the Automatic Identification of News Tweets is elaborated in the paper [11]. All the identified news tweets have *URLs* in their text, which are the links to the actual news article where they are originally published.

The next part of the framework scrapes the actual news articles linked to the URLs in the News tweets. News articles are scraped from its original news sources and stored along with the references of the respective news sources. Opinion diversity is expected among the news articles collected for each topic as they might have discussed the topic in different perspectives. Relevant news articles are selected for each topic considering the features related to the content, social context and temporal aspects for further processing. For example, the news articles collected for one of the trending topic on twitter, "Nipah Virus" have included discussions on Nipah virus from perspectives like, the preparedness of hospitals and medical staff to deal with it, preventive steps through public awareness, different treatment procedures, and some articles included the statistics related to this epidemic, and other. Hence the news articles related to each perspective should be segregated from the others as a unifiable group for better comprehension through summarization of each group.

The news articles are grouped based on their semantic similarity into smaller clusters using clustering techniques. The paper investigates the effectiveness of vectorization for capturing the semantics of the documents using different state-of-the-art methods. The unifiable news article identification phase of the proposed framework studies *TD-IDF, Word2Vec* and *Doc2Vec* vectorization methods in detail and clusters the articles using the *k-means* clustering [12]. We elaborate on the proposed method for identifying Unifiable News Articles in Section V.

Each cluster thus obtained consist of multiple documents which discussed the topic in a specific perspective and hence are unifiable for a summary generation. The documents in each cluster are summarized using a Hybrid Multi-Document Summarization methodology proposed by the authors, details of which are elaborated in the paper [13]. The Hybrid Multi-Document Summarization is implemented using Deep Learning architecture with a cascade of Abstractive and Extractive summarization approaches.

The final summaries generated for the individual clusters could be used to build the underlying stories of the most trending topics on Twitter. Each statement in the final summary contains the references to the original news source, useful for further study, possibly, for resolving any conflicts.

IV. Vectorization of Text Documents

The section presents three commonly used methods for converting text documents to a vector representation. The proposed work studies tf-idf, Word2Vec, and Doc2Vec vectorizations in detail and experiments the approaches for clustering news articles using the k-means algorithm.

A. Term Frequency-Inverse Document Frequency (tf-idf)

The tf-idf score increases proportionally by the count of a particular word appearing in a given document (term frequency) and is neutralized by the count (inverse-document frequency) of the total number of documents in the corpus. The tf-idf matrix transforms all documents into rows, with all words in the documents stored as column vectors. The product of ***tf*** and ***idf*** is used to calculate the ***tf-idf*** score,**.**

$$tfidf(t,d,D)=tf(t,d)\times idf(t,D)$$

where ***t*** denotes the terms; ***d*** denotes each document; ***D*** denotes the collection of documents.

Term Frequency (**tf**):

tf(t,d)= (Number of times the term t appears in a document) / (Total number of terms in the document, d).

Inverse Document Frequency (**idf**):

$idf(t,D)= log_e$*(Total number of documents, D / Number of documents with term t in it).*

B. Word2Vec

Bengio et al. [14] first introduced the term word embedding in the year 2003. Collobert and Weston [15] were the first to depict the advantage of pre-trained word embeddings in 2008 and proposed the neural network architecture used in most of the recent approaches. Mikolov et al. [3], created Word2Vec model that revolutionized the use of word embeddings by introducing a toolkit that allows seamless training to the models and use of its pre-trained embeddings. Pennington et al. [2] in 2014, released GloVe, a competitive set of pre-trained word embeddings without using neural networks, signalling that word embeddings had reached the mainstream.

Word2Vec is a predictive neural-based word embedding model that provides probabilities to the words rather than frequencies. Word2Vec models process large text corpus to produce the output vectors using shallow neural network architectures. Though Word2Vec is a shallow neural network, the resulting vector representations are used for sophisticated language modelling by Deep learning architectures. Word2Vec is a combination of two models, the continuous bag of words (cbow), where the context of the word is used to predict the actual word and the skip-gram(sg), where the word is used to predict the target context. Skip-gram(sg) model could be used on large datasets to produce more accurate results.

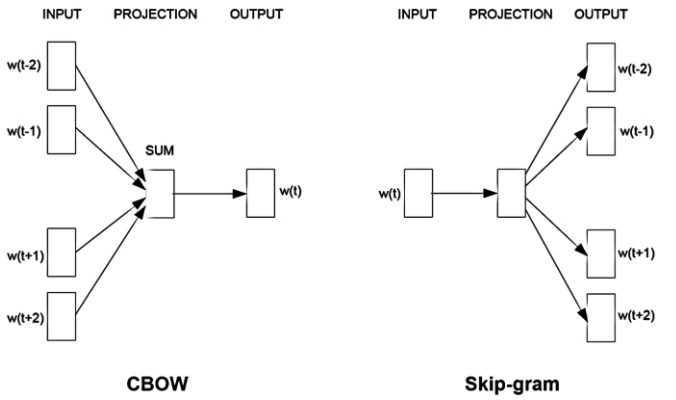

Fig. 2. CBOW and Skip-Gram Models, Adapted from Mikolov et al. 2013.

A snapshot of the Word2Vec models proposed by Mikolov et al. [3], is shown in figure 2, continuous bag of words methods predicts the word w(t) by taking the corresponding words as input. Also, the skip-gram techniques can predict the context words given the input word w(t).

C. Doc2Vec

Dealing with longer sentences, paragraphs or documents of varying lengths requires macro-level embedding techniques and Doc2Vec is devised for such scenarios. Doc2vec is an extension to the Word2Vec algorithm for learning continuous representations of larger chunks of text like sentences, paragraphs or the entire document in terms of constituent word embeddings. An additional sentence/paragraph token is added to obtain the document vectors.

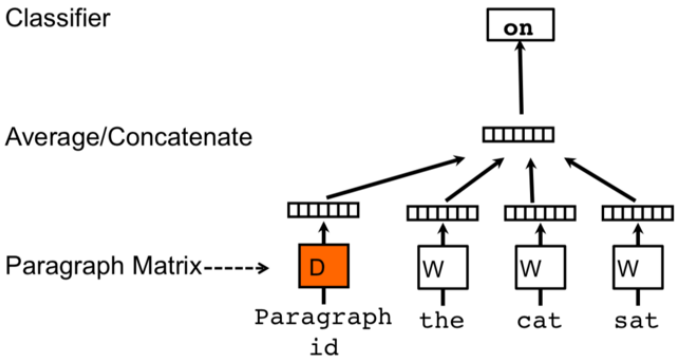

Fig. 3. Distributed Memory Paragraph Vectors(dmpv), Adapted from Mikolov et al. 2014.

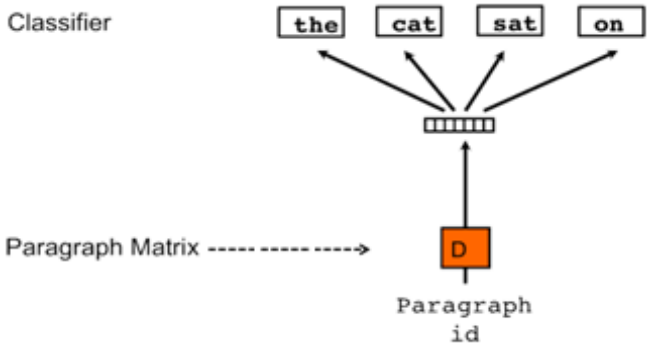

Fig. 4. Distributed Bag of Words(dbow), Adapted from Mikolov et al. 2014.

The Doc2Vec [5] model architecture also has two underlying algorithms the distributed memory paragraph vectors(dmpv) as shown in figure 3 and the distributed bag of words (dbow) shown in figure 4.

V. Identifying Unifiable News Articles using K-Means Clustering

Clustering algorithms for analyzing text, places documents into groups called subsets or cluster that are internally coherent and externally coupled. Text clustering is a procedure for cluster analysis of textual documents useful for machine learning (ML) and natural language processing (NLP) applications.

The procedure for text clustering includes a series of transformations of the original document, before obtaining the vector representation of the text. The documents are first pre-processed to remove all unwanted characters like punctuations, numbers, and other symbols, as they are in no way helpful for the clustering task. Later methods like stop words removal and stemming are applied to refine the text even more. After pre-processing, the normalized vectors of the text documents can be produced using any of the previously explained vectorization methods. The vectorized form of the input data is used to performs a k-means clustering over the set of documents and produce smaller groups of documents based on the given k value. The proposed work experiments with all the three vectorization methods discussed above to generate the vector representations for clustering the news articles using k-means.

k-means is an unsupervised learning algorithm that allows to group or clusters data points within your data based on some similarity. k-means is a grouping technique that groups the data into k clusters and assigns each data point to a particular cluster based on the similarity or distance measure to its centroid. The *k* in the k-means implies to the number of clusters and certain techniques like the “elbow method”, help in choosing the optimal number of clusters for large documents. The steps for k-means clustering are as follows:

1) Randomly chosen *k* data points act as the cluster centroids as the starting point, the remaining data points get assigned based on the nearest centroid within the cluster using any of the distance or similarity measures.

2) Reassign the respective centroids, after calculating the mean of all the data points in the individual clusters.

3) Repeat steps 1 and 2 until no new centroids constitute.

The clusters obtained using k-means on the news articles are chosen as the Unifiable groups that segregate the articles in the corpus based on the similarity of the news articles in capturing the different perspectives of the news articles. The identified groups of unifiable news articles can be summarized to get the underlying story for the trending topics in different perspectives.

VI. Dataset and Experimentation

The proposed work is to study different vectorization models and access the performance of k-means clustering on news documents. Three most commonly used vectorization

techniques were studied using DUC 2004 corpus for identifying clusters of unifiable news articles that could be summarized later in the proposed framework. tf-idf, Word2Vec and Doc2Vec vectorization methods were applied on the same data and clustered using k-means.

A. Dataset

Document understanding conference [16] (DUC) 2004, consist of 500 documents organized in 50 clusters, each with approximately 10 news articles related to a specific news topic form NEWSWIRE. This structured organization of the dataset helps us in estimating the purity of the clusters formed using k-means as each folder of DUC 2004 inherently is a cluster of unifiable news articles where all files in the folders relate to the same news topic.

Figure 5 displays the file size distribution of all the files from DUC 2004 in kilobytes. About 58% of the total files are of size 2KB and 3KB, and the rest are either too big or too small to form unifiable clusters.

B. Results and Evaluation

For interpreting the results and calculating the purity of the clusters, the proposed work is repeated for five times randomly selecting 10 folders and experimented with all the three vectorizing models. The averaged values of purity for all the five runs, for each of the vectorization methods, were tabulated and compared. The tf-idf vectorization model produced the best results in terms of purity of the clusters. Table 1 shows the purity scores of the three models on 10 randomly chosen folders containing 8 files each, with files whose size is in the range of 2KB or 3KB.

The experimental results indicate that the tf-idf vectorization method has produced more appropriate clusters for the articles with high purity value compared to Word2Vec and Doc2Vec vectorization methods. However, the tf-idf score depends on document frequencies for the words in the vocabulary and hence should be refreshed upon the arrival of a new chunk of news articles. Hence, tf-idf vectorization is preferable for handling the static collection of documents.

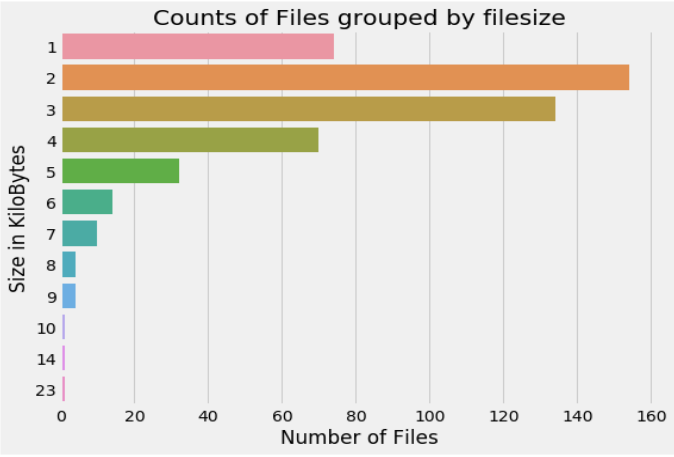

Fig. 5. Distribution of Files in KiloBytes.

TABLE I. PURITY SCORES FOR DIFFERENT VECTORIZATION

	TF-IDF	Word2Vec	Doc2Vec
Purity Score	**0.98**	0.89	0.95

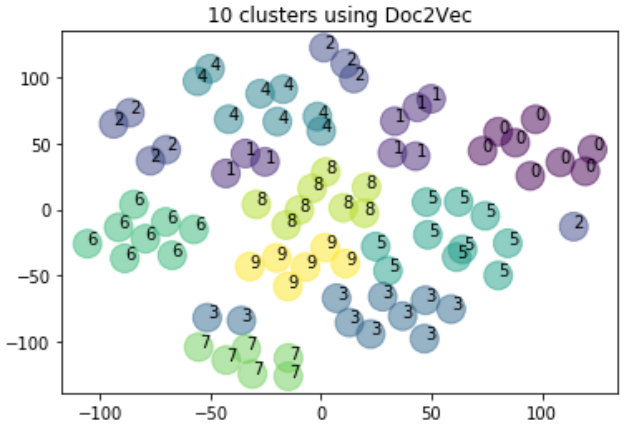

Fig. 6. Clusters using Doc2Vec.

Due to the limitation of tf-idf vectorization in handling corpora with continuously changing vocabularies, vectorization using Word2Vec and Doc2Vec embeddings offer better alternatives. Word2Vec and Doc2Vec could be used when there is an incremental set of news articles, and among the two methods, Doc2Vec approach produced high-quality clusters. Figure 6 depicts the Multi-Dimensional Scaling (MDS) visualization of 10 clusters produced by k-means with Doc2Vec vectorization of news articles.

VII. CONCLUSIONS AND FUTURE WORK

The proposed work introduces the framework for the Identification and Hybrid Summarization of news articles related to trending topics on social media. Different news articles related to a topic may have different perspectives and hence should be segregated into different unifiable groups based on their semantic similarity. The effectiveness of three vectorization methods, namely tf-idf, Word2Vec and Doc2Vec, for capturing the semantic similarity of news articles for identifying unifiable groups was investigated by clustering the vectorized news articles using the k-means algorithm.

The results obtained upon experimentation using documents available in DUC 2004 benchmark dataset are in favour of tf-idf vectorization with high purity cluster formation for static datasets. However, Doc2Vec vectorization is suggestable for handling news articles on trending topics as they require dynamically changing vocabularies.

The authors of the proposed work investigated the effectiveness of the existing text vectorization methods that generate single level word embedding of dynamically changing vocabularies required for clustering of news articles. As a future extension to this work, the authors propose to apply multi-level word embeddings using ELMo and BERT for building deep learning models for clustering news articles.

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A Proposed Model for Detecting Facebook News' Credibility

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Arab Academy for Science, Technology and Maritime Transport, Egypt[3]

***Abstract*—Social networks are currently one of the main News' sources for most of their users. Moreover, News channels also consider social networks as main channels not only for spreading the news but also for measuring the feedback from their followers. Facebook Followers can comment or react to the news, which represents the follower's feedback about this topic. Therefore, it is a fact that measuring the News' credibility is one of the important tasks that could control the propagation of the fake news as well as the number of News' followers. The proposed model in this research highlights the impact of the News' followers on detecting the News' polarity either it is fake or not. The proposed model focuses on applying an intelligent sentiment analysis using Vector Space Model (VSM) which is one of the most successful techniques on the users' comments and reactions through the emoji. Then the degree of credibility is determined according to the correlation coefficient. An experimental study was applied using Facebook News dataset, which included the News and the followers' feedbacks.**

***Keywords*—Social network; vector space model; correlation coefficient; sentiment analysis**

I. Introduction

Earning experiences from colleagues and friends has been considered long time ago [1] [2] [3] by different methods, however, a focus on social media source is recently highlighted. Considering applying mining techniques in different fields to support text analysis as well as emotion analysis has been proposed by different research such as in [4] [5] [6] and in [7]. The popularity of Social Networks are continuously increasing not only from population but it is also considered as a main resource to formal News' institutes. This population has led to a continuous focus from a large number of researchers [8], [9] [10]. Specifically, Facebook has a leading position among other social networks [11]. One of the main popular features in Facebook is the ability to express and share a reaction by different methods either by text, image, emoji, and others as well as the ability to control the privileges of others on this reaction. However, users may share fake news with no intention as they have no way to measure its credibility while they may become one of the main resources of credibility detection [12] [13]. Therefore, many research have been proposed for detecting the posts' polarity [9] as well as the fake news [14] [15].

Focusing on Facebook, different situations may be highlighted, the users' contribution may be not relevant to the post or a spam [13] [16]. Therefore, focusing on different users' response such as comments and emotions is considered one of the success factors for measuring credibility [17] [18]. The proposed model in this research considers detecting the credibility according to the comments and emotions analysis.

The remaining of this paper is organized as follows. Section 2 provides the technical background that is used in the rest of the paper. Section 3 defines our proposed model and the modifications that had been done on the original one. Section 4 studies our methods in a case study. Finally, Section 5 contains the conclusion and future work.

II. Background

There are several definitions and techniques used in the proposed model. Each one used for a specific purpose identified in section IV. These definitions and techniques are:

- Facebook reactions and their polarity [17] [8] [9].
- Vector space model: for measuring the text similarity between the post and comments on this post [19] [20].
- Sentiment analysis: for measuring the polarity of the comments on the tested post [21].
- Correlation coefficient: for measuring the convergence between the result from Facebook emotions and the analysis of post [21] [22].

A. Facebook Reactions

Facebook released the ability to respond by emotions in February 2016 additionally to the like emotion. Currently, six emotions are available to express the users' reaction represented in figure 1, they are as follows [23]:

a) Like: represents liking of the proposed post or comment.

b) Love: represents more than liking and express more empathy about the post.

c) Wow: represents surprising feeling that the post expresses unexpected act or event.

d) Haha: represents a funny reaction like irony or laugh.

e) Sad: represents sadness about specific action or event, also it reflects the refusal of the post.

f) Angry: represents the disliking of the post or comment.

Figure 1 demonstrates the well-known Facebook reactions:

Fig. 1. Facebook Reactions [24].

These emotions have different polarity [25] [14] [26], they are either positive (+1), negative (-1), or idle (0), and these emotions are classified according to their polarity. The following is a classification for the emotions:

a) Like: the default response which indicates that the post is seen, (0 polarity).

b) Love: a positive response which indicates that the reader admire the post contents, (+1 polarity).

c) Wow: a positive response which expresses the reader finds the post interesting, (+1 polarity).

d) Haha: a positive response which expresses that the reader finds the post funny, (+1 polarity).

e) Sad: a positive response which represents the reader sadness for the post contents, (-1 polarity).

f) Angry: a positive response which expresses the negative effect on the reader from the post contents, (-1 polarity).

B. Vector Space Model

Different algorithms have been proposed [27] [28] [29], however, Vector space model (VSM) is one of the most popular and successful. VSM contributes to an algebraic model that is able to provide a vector representation to the text document. VSM is popularly applied for index terms extraction, documents indexing, and documents ranking [19]. Measuring text documents similarity is applied using similarity measures such as cosine similarity [30] [31] , Euclidian distance [32].

C. Sentiment Analysis

Sentiment Analysis refers to the process of analyzing a document [21] which focus on a determined topic such as a situation or a product and classify the type of document according to the owner's attitude, either he likes or dislikes this document content with respect to the strength level of this attitude.

Text emotion classification methods have been demonstrated in different research with a filtration approach such as in data [33] [34]. Sentiment analysis could be performed using different approaches such as Sentiment Identification Algorithm which is Compositional Semantic Rule, Numeric Sentiment Identification, Vector space model, and Bag-of-Word and Rule-based. All these algorithms are used in Machine Learning Model which involves several classifiers such as Decision Tree, Random Forest, Logistic Correlation and Neural Network. [25].

D. Correlation Analysis

Correlation approach measures the degree that two variables are supporting each other [35]. The correlation coefficient measures how much a variable has an impact in changing the other variable performance and is able to change its value.

- A correlation coefficient is +1 when the increase of the variable leads to a fixed proportion increase positively to the dependent variable.
- A correlation coefficient is -1 when the increase of the variable leads to a to a fixed proportion decrease to the dependent variable.
- A correlation coefficient is 0 indicates that the two variables have no relation and there is no impact of one to the other.

III. Proposed Model

The proposed model follows the previously discussed techniques for measuring the post credibility [36] [37], this section demonstrates how these techniques are correlated and reformed in a homogenous model to support the required target. The proposed model is divided into three main phases as follows:

A. Preprocessing Comment Text

The text preprocessing is processed through several steps: [26] [20] [38].

Step 1: Spelling check

One of the main steps is performing a spelling check as preliminary step to avoid errors in the following phases. This step requires a dictionary that contains expressions in different forms like verbs, adjectives, nouns, etc.

Step 2: Text Preprocessing

This step aims to perform a tokenization process or text normalization. It includes eliminating white space and punctuations, Stemming, stop word removal and case folding by transforming the capital letter to lower case.

Step 3: Part of Speech Tagging

Part-of-Speech Tagging targets to read the text in a specific language and assign a tag to each token to define its type such as nouns, verbs, adjectives, etc.

Step 4: Building Vector

In this step, the extracted tokens are stored as a vector. This step is preparatory step for applying the vector space model for measuring the sentiment analysis in the next process. As Vector space model depends mainly on the idea of similarity, therefore, cosine similarity measure [8] was selected as it proved to be efficient in the field of sentiment analysis.

B. Sentiment Analysis of Comment Text

In this phase, applying sentiment analysis techniques is performed for the main research target. As previously stated, different approaches could be selected according to the document nature, in this research and according to the literature review that is performed by the authors, SVM is the technique that will be applied in the proposed model.

Performing documents classification for the posts' comments is performed using the lexicon approach in [8]. Mohsen and his colleagues developed an opinion lexicon in [8] that contains 6800 words classified as positive or negative. Then applying cosine similarity for the created vectors is performed with measuring the polarity of each as discussed in previous sections.

C. Calculating the Correlation Coefficient

The Facebook posts are classified to negative or positive according to post's reactions, and each comment on the post is classified by using sentiment analysis.

For each post, the correlation coefficient value is calculated between the results of classification of reactions and comments, targeting to determine if the classification of comments is similar to the classification reactions.

The correlation coefficient is calculated through the following equations: [21] [39].

$$r = \frac{1}{n-1}\left[\frac{\sum_x \sum_y (x-\bar{x})(y-\bar{y})}{S_x S_y}\right]$$

The overall results give an indication of the post credibility according to the degree of similarity between comments and reactions.

IV. Experimental Results

An example for the model process is as follows:

Post A has the values illustrated in table I:

Total number of Negative reactions=

Sad (140) + Angry (195) = 335

Total number of Positive reactions =

Love (91) + Wow (35) + Haha (28) =154

Percentage of Negative =

$$\frac{(\text{Total Number of negative})}{(\text{Total Number of reactions})} X\ 100 = 68.50$$

Percentage of Positive =

$$\frac{(\text{Total Number of positive})}{(\text{Total Number of reactions})} X\ 100 = 31.49$$

TABLE I. Post's Reactions Example

Like	Love	Wow	Haha	Sad	Angry
250	91	35	28	140	195

Then the post is classified to be Negative

The comment classification is classified according to the vector space model by measuring the similarity. The lexicon contains 6800 words classified as positive or negative with the ability for enrichment as discussed in [8]. Each class is considered as a document, and the comment is also considered as a document. Then the similarity between the comment and each document class, the higher value is the classified class.

For example, a comment state that: "it is a bad product."

After applying text preprocessing, there are two extracted words: bad and product, and the result shown in table II.

These results are calculated for each post as illustrated in table III.

TABLE II. Comment Classification Example

Comment ID	Negative	Positive	Result
1423_25	1	0	Positive

TABLE III. Post Classification Example

Post ID	Negative comments	Positive comments	Result
1423	258	349	Positive

V. Evaluation

Although the experimental phase in researches can use benchmark resources [40] [41] [42] [43] [44], however, applying the proposed approach on a real case highly prove the approach effectiveness [45] [46] [47] [48].

The dataset sample followed the research in [49] [50]for selecting the suitable sampling technique. It was collected, like the following:

The research focused on 8 Facebook pages News agencies and 21 posts selected from the Facebook pages shown in table IV.

Each post has a number of comments; a total number of comments in the dataset is **1523**. For each post, we collected the emoji, and the polarity classification is calculated as shown in table V and table VI. For the comments the polarity classification is calculated, fig. 2 shows the distribution of classes for each post, the classes are positive, negative and neutral. The post was classified according to the biggest value of the three classes for the comments.

TABLE IV. Facebook Pages and Selected Posts

No	Facebook News Page	Number of selected posts
1	BBC News	3
2	BBC Family News	3
3	CBS News	3
4	NBC News	3
5	NPR news	3
6	Politico	2
7	NY Daily News	2
8	Democratic Underground	2

TABLE V. POSTS WITH THEIR EMOJI

ID	Facebook Page_ Post ID	Angry	Ha-ha	Like	Love	Sad	Wow	Positive	Negative	Sentiment
1	228735667216_ 10154890879532217	54	24	993	144	12	24	192	66	POSITIVE
2	228735667216_ 10154890968202217	172	8	994	11	783	264	283	955	NEGATIVE
3	228735667216_ 10154890852247217	5	12	2034	369	6	45	426	11	POSITIVE
4	228735667216_ 1426789250735491	6	0	2262	754	1989	11	765	1995	NEGATIVE
5	228735667216_ 10154890645702217	65	513	4336	54	128	815	1382	193	POSITIVE
6	228735667216_ 10154890600247217	25	136	2549	195	2	17	348	27	POSITIVE
7	228735667216_ 10154890480662217	0	2	4123	1005	2256	41	1048	2256	NEGATIVE
8	228735667216_ 10154890399087217	51	273	1302	24	39	190	487	90	POSITIVE
9	228735667216_ 1887717684813716	403	10	2169	15	874	115	140	1277	NEGATIVE
10	228735667216_ 10154889414912217	745	1	1374	16	722	106	123	1467	NEGATIVE
11	228735667216_ 10154889386187217	4	8	2667	195	729	9	212	733	NEGATIVE
12	228735667216_ 10154889308562217	153	7	983	10	323	12	29	476	NEGATIVE
13	228735667216_ 10154889223727217	626	70	747	23	28	25	118	654	NEGATIVE
14	228735667216_ 10154889016422217	3	47	11024	1120	24	2531	3698	27	POSITIVE
15	228735667216_ 10154888875107217	3	1117	3488	64	36	602	1783	39	POSITIVE
16	228735667216_ 10154888663672217	2	8	3644	335	1	59	402	3	POSITIVE
17	228735667216_ 10154888522807217	5356	4235	5455	214	259	1231	5680	5615	POSITIVE
18	228735667216_ 10154888481772217	5886	253	8299	163	948	1440	1856	6834	NEGATIVE
19	228735667216_ 10154888328917217	289	34	1075	52	13	36	122	302	NEGATIVE
20	228735667216_ 10156521638374968	2	75	811	17	23	231	323	25	POSITIVE
21	228735667216_ 10155178616101971	285	3941	11194	175	66	4830	8946	351	POSITIVE

TABLE VI. POST'S COMMENTS WITH THEIR SENTIMENT ANALYSIS

ID	Facebook Page Post ID	message	Sentiment
1	228735667216_ 10154890879532217	We are speaking to NRA supporters as well as Women's March supporters	POSITIVE
2	228735667216_ 10154890879532217	If you are just joining us, we are outside of the headquarters of the National Rifle Association outside of Washington DC. The Women's March are demonstrating and then marching to the Department of Justice to protest a controversial commercial.	NEGATIVE
3	228735667216_ 10154890879532217	Do you know how backward America is in allowing people to have guns? Nineteen kids per day die in the USA by accidental shootings... Constitutional rights! Get a grip.	NEGATIVE
4	228735667216_ 10154890879532217	People who legally own guns often seem all too eager for an opportunity to shoot someone. Statistics show that guns bought 'for protection' very rarely get used as intended. Ask any ER doctor.	NEGATIVE

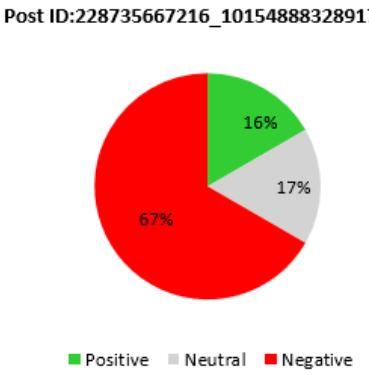

Fig. 2. Pie Chart of Post's Comments Classification.

Table VII shows the posts polarity according to their comments for the specific Facebook page. The final step targets to calculate the credibility score by measuring the correlation coefficient between the Facebook emoji reactions on the post and the polarity of the comments on the same post, the degree of matching between the emoji reactions and polarity of comments represents the degree of credibility of Facebook post as shown in table VIII.

TABLE VII. FACEBOOK PAGE'S COMMENTS POLARITY

ID	Facebook Page_ Post ID	Positive	Negative	Sentiment
1	228735667216_ 10154888328917217	2	8	NEGATIVE
2	228735667216_ 10154888481772217	8	8	NEGATIVE
3	228735667216_ 10154888522807217	16	8	POSITIVE
4	228735667216_ 10154888663672217	54	18	POSITIVE
5	228735667216_ 10154888875107217	58	38	POSITIVE
6	228735667216_ 10154889016422217	72	26	POSITIVE
7	228735667216_ 10154889223727217	8	12	NEGATIVE
8	228735667216_ 10154889308562217	40	30	POSITIVE
9	228735667216_ 10154889386187217	26	8	POSITIVE
10	228735667216_ 10154889414912217	16	46	NEGATIVE
11	228735667216_ 10154890399087217	44	42	POSITIVE
12	228735667216_ 10154890480662217	63	30	POSITIVE
13	228735667216_ 10154890600247217	35	47	NEGATIVE
14	228735667216_ 10154890645702217	44	43	POSITIVE
15	228735667216_ 10154890852247217	66	12	POSITIVE
16	228735667216_ 10154890879532217	31	50	NEGATIVE
17	228735667216_ 10154890968202217	27	53	NEGATIVE
18	228735667216_ 10155178616101971	6	4	POSITIVE
19	228735667216_ 10156521638374968	40	34	POSITIVE

The value of negative for the post is replaced with (-1), and the value of positive is replaced with (+1) for calculating the correlation coefficient.

The correlation coefficient for the values in table VIII is calculated to be 0.337099931.

The correlation coefficient value is between 0 to 1 according to the strength or similarity between the two variables.

The credibility rank of the previous posts for the Facebook page as a percentage is: 0.3371 * 100 = 33.71 %

So the rule extracted from previous calculations is:

The Posts of a Facebook page with ID (228735667216) is 33.71 %

After reviewing the presented example with experts, it is confirmed that that the results shown is related to the post status. Therefore, after applying the proposed model to the collected dataset and reviewing the results with an expert, the proposed model is found to have an accuracy of 95% for detecting the News' credibility. However, more investigation was required for manipulating the abnormality to increase the accuracy.

Credibility percentage increases the share and use of the UGC contents that it is probably credible, and at the same time, it ignores the UGC that it is not probably credible. Many enhancements could be applied to increase the accuracy of the model, like applying deeper data mining or machine learning techniques, which will be our target for future work.

TABLE VIII. FACEBOOK PAGE (228735667216) POSTS' ANALYSIS

ID	Post ID	Emoji	Comment	Emoji	Comment
1	10154888328917217	NEGATIVE	NEGATIVE	-1	-1
2	10154888481772217	NEGATIVE	NEGATIVE	-1	-1
3	10154888522807217	POSITIVE	POSITIVE	1	1
4	10154888663672217	POSITIVE	POSITIVE	1	1
5	10154888875107217	POSITIVE	POSITIVE	1	1
6	10154889016422217	POSITIVE	POSITIVE	1	1
7	10154889223727217	NEGATIVE	NEGATIVE	-1	-1
8	10154889308562217	NEGATIVE	POSITIVE	-1	1
10	10154889414912217	NEGATIVE	NEGATIVE	-1	-1
11	10154890399087217	POSITIVE	POSITIVE	1	1
12	10154890480662217	NEGATIVE	POSITIVE	-1	1
13	10154890600247217	POSITIVE	NEGATIVE	1	-1
14	10154890645702217	POSITIVE	POSITIVE	1	1
15	10154890852247217	POSITIVE	POSITIVE	1	1
16	10154890879532217	POSITIVE	NEGATIVE	1	-1
17	10154890968202217	NEGATIVE	NEGATIVE	-1	-1
18	10155178616101971	POSITIVE	POSITIVE	1	1
20	1426789250735491	NEGATIVE	POSITIVE	-1	1
21	1887717684813716	NEGATIVE	POSITIVE	-1	1

VI. CONCLUSION AND FUTURE DIRECTIONS

Social Network is a main source of News which leads to the extreme importance for these sources. However, it is a fact that it is also considered a gate to rumors. The users' reaction is a central factor for spreading the News either it is real of Fake. Therefore, this research focused on measuring the News' credibility in Social media in general and on Facebook in specific. The proposed model was based on three main pillars, an enrichment sentiment lexicon approach, a sentiment analysis approach, and determining correlations. The proposed model considered both the users comments and emotions. The main idea was relating the post contents with the users' response. The results showed the success of the proposed model, however, it only included text comments, and it needs to include other types of comments including images. Moreover, the paper only included English language, therefore, including multilingual component to the proposed approach is one of the key factors in the future directions. A future direction was to improve the accuracy level by considering an enhancement to the SVM approach as well as including the users' trend in their reactions by applying a semantic network that relates between the News networks with the users' network.

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Cyber Terrorist Detection by using Integration of Krill Herd and Simulated Annealing Algorithms

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***Abstract*—This paper presents a technique to detect cyber terrorists suspected activities over the net by integrating the Krill Herd and Simulated Annealing algorithms. Three new level of categorizations, including low, high, and interleave have been introduced in this paper to optimize the accuracy rate. Two thousand datasets had been used for training and testing with 10-fold cross validation for this research and the simulations were performed using Matlab®. Based on the conducted experiment, this technique produced 73.01% accuracy rate for the interleave level; thus, outperforming the benchmark work. The findings can be used as a guidance and baseline work for other researchers with the same interest in this area.**

Keywords—Krill Herd; web content classification; cyber terrorists; simulating annealing

I. Introduction

The cyber terrorist activities have increased lately through the web posing challenges to people around the world [1]. A cyber terrorist is defined by Al Mazari [2] as a criminal who uses computer technology and the Internet with the intention of causing violence or spreading ideology to threaten people. Furthermore, cyber terrorists are those who perform act of terrorism and profess motivations or justify their violent tactics according to their own goals and intentions [3]. Hence, this work defines terrorism as any act that is intended to harm others based on ideological motivations to justify their crimes.

It is important to reduce the number of features in order to classify the contents of cyber terrorists. The bag of words (BoW) consists of various numbers of words representations. It is one of the simpler and more preferred models as it represents web as a set of distinct words that are not compatible with each other by ignoring the order and meaning of the words. Sometimes a situation may arise when the number of words that are available in the web are considerable. A very high dimensionality might have an adverse effect on the feature space resulting in destructive influences. Besides, it degrades the performance of the entire system as well as the performance of the content classifier. Since data in content classification are of high dimensions, natural dimensionality reduction becomes a necessity to increase efficiency and accuracy [4]. The current study focuses on the dimensionality of the cyber terrorists.

This paper is presented based on the following sections. Section II discusses main related works in feature selection (FS) and cyber terrorist's domains. Section III evaluates the effect features of on three classifiers algorithms and the findings are presented in section IV. Section V concludes this paper and offers suggestions for future work.

II. Related Works

Traditional feature selection algorithms such as information gain and Chi-Squared are problem dependent and the dependencies of features are ignored [5]. This motivates the researchers to dwell into other FS methods like meta-heuristic algorithms and utilize them as feature learning for cyber terrorist's classifiers in order to be able to detect the terrorist activities in the dark web. Investigation and creation of novel approaches for dealing with the problems of feature selection dimensionality are still interesting areas for researchers mainly with regard to spam classifiers. Hence, employing the approaches of FS in [6] and [7] are discussed "(a) performance improvement such as predictive accuracy, speed of learning and quality of rules; (b) data visualization and simplification to visualize the data for model selection; and (c) dimensionality reduction and removing the noise and irrelevancy".

Some studies have been conducted on meta-heuristic techniques such as the local search and the population-based approach for the heuristics and hybrid meta-heuristics. A meta-heuristic technique is a technique that is based on computational approaches and is proven very effective as it optimizes the problem frequently through its improvement in which a candidate solution is employed. The help of this candidate solution deputed an improvement in terms of a given measure of quality [8]. The core idea of a simulated annealing designed and developed in [9] is on hil climbing-based approaches by using possibility for the escape of a local optima problem.

There are several researchers who have hybridized single-based methods with other approaches leading to improved effectiveness. For instance, [10] and [11] employed the Particle Swarm Optimization (PSO) for feature subset selection, utilizing the k-nearest neighbor as classifier, and BOW as extraction. On the other hand, they utilized filter-based approaches including Minimum Redundancy Maximum Relevance (mRMR), Information Gain (IG) and other five familiar wrapper-based approaches including ant colony optimization and genetic algorithm. Based on the results, it is revealed that the particle swarm as a feature selection method is better than information gain, term variance, fisher score and mRMR methods. Moreover, the particle swarm as feature selection is better than wrapper-based approaches utilizing all approaches of the k-nearest neighbor as the classifier. [12] Employed query expansion ranking as feature selection for sentiment analysis and compared it with state-of-art methods namely, document frequency difference, Chi square, information gain, and optimal orthogonal centroid. On the other hand, they compared four classifiers, namely Naïve

Bayes Multinomial, Support Vector Machines, Maximum Entropy Modeling, and Decision Trees. Their results showed that the proposed method of query expansion ranking as feature selection is better than state-of-arts. In addition, compared with four classifiers, the naïve Bayes multinomial is better than others as a classifiers algorithm are. Labani [13] also used a filter method named Multivariate Relative Discrimination Criterion for text classifier as feature selection. They proposed their method to reduce the redundant features in text categorization and they used three datasets to evaluate their proposed method. Then, they compared it with the state-of-art, namely Relative Discrimination Criterion, Information Gain, Gini index and Minimal-Redundancy-Maximal-Relevance. In addition, they used three classifiers algorithms, namely Multinomial naïve Bayes (MNB), Decision Tree (DT) and Multilayer Perceptron (MLP) classifiers. Based on their results, their proposed method of Multivariate Relative Discrimination Criterion as filter approach reduced the number of redundant features and increased the performance of text classifiers. On the other hand, their results did not mention which of three classifiers was the best. The next section evaluates the three classifiers algorithm to address the effect of features on the classifiers and outlines why krill heard is desired as a feature selection.

III. Methodology

A. Evaluating Three Classifier Algorithms

In order to illustrate the behaviour of three classifiers, BOW rule was applied as the extraction method.

$$\mathrm{DB} = \sum_{i=\mathrm{n}}^{\mathrm{i}=1} \left(. \left(I^{i=n}_{i=1}\right). \left(BOWi\right) \right) \quad (1)$$

Where I is the first term, n is the number of terms extracted and I^i equals to Ideological Concepts; where I^1 is Salafi Jihadist ideology such as Al Qaeada, I^2 is Takfiri Ideology such as ISIS and I^3 is Spiritual Mentor such as: Usama Bin Laden, Abu Baker Al Baghdadi, and Al Mamakdsi.

The datasets were taken from *Tawhid* consisting of 800 webs. This experiment can be used for the fitness function as an evaluation measure. Table I provides the summary of the results for the three classifiers namely KNN, NB, and SVM by comparing the accuracies achieved using the BOW extraction method. The results indicate that the SVM classifier achieved the best results in DS2, with an accuracy rate of 69.94%. In addition, the NB classifier is the best classifier in DS3 and the KNN classifier is the best one in DS1. It is concluded that although the SVM outperforms the NB and KNN in terms of the accuracies achieved, the performance of document classification is still inconclusive. The number of better accuracies achieved by NB and KNN classifiers is near to SVM classifier results.

Evaluation of the results with the number of features used in each dataset taken into account shows that the NB classifier performs better when number of features is low. That is, the number of features in DS3 is 4636. On the contrary, for SVM, the accuracy result in DS2 equals to 69.94%, which has the highest number of features of 7096. Finally, for the KNN classifier, the effect of the number of features on the accuracies is inconclusive.

B. Employed Krill Herd WITH Simulated Annealing as Feature Selection

This section of the algorithm is used to describe the various techniques employed in the searching of the proposed Krill Herd. The searching technique is applied with the help of any feature selection algorithm that uses Krill Herd as feature selection (KHFS). Similar to other metaheuristic techniques, the proposed mechanism starts with an initial value of the population that is considered as the forced basis called the Krill density and the best individual that is chosen as a Krill. HSFS technique is weaker in terms of local searches and has a low convergence rate.

Due of this factor, it is easily available to run into various local optimum conditions rather than running it into the global optimum conditions [14]. In general, this is a huge drawback with harmony search algorithm. Such algorithm is used to employ various control parameters, which the KH algorithm actually avoids and does not make use of. The KH algorithm will have only one control parameter limit if common controlling parameters that are considered the maximum equation numbers and the size of the population of the Krill are excluded. HS algorithm has three control parameters namely phmcr, p par, and bw [15]. A fresh meta-heuristic algorithm like Krill Herd algorithm optimization is created to fill such gaps [16].

In this part of the study, the algorithms that are proposed to represent various webs were used as vector-space models. Therefore, as a common observation, it can be considered that the terms available as one-dimensional or multidimensional web space can be taken as di = (w_{i1}, w_{i2} . . . w_{in}). The proposed algorithm employs some representations where they codify the whole P of the features set in a vector of length m, where m is the number of the features; this is illustrated in Table 2. Each element of this vector is the label where the features are either selected or dropped. An example of solution representation is illustrated in Table II. In this case, 5 features {3, 4, 6, 7, 8 and 10} are selected. The others are dropped {1, 2, 5 and 9}.

TABLE. I. Results for the Three Classifiers using BOW

DS		**KNN**	**NB**	**SVM**	**Best**	
	# features				Best	Accuracy
DS1	4731	59.88	53.89	55.50	KNN	59.88 %
DS2	7096	55.24	53.60	69.94	SVM	69.94 %
DS3	4636	59.83	66.83	61.67	NB	66.83 %

TABLE. II. Represent the Selected Features

1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
0	***0***	***1***	***1***	***0***	***1***	***1***	***1***	***0***	***1***

1) Simulated annealing: The simulated annealing, as proposed by [17], can be considered a single heuristic solution, which is available on the basis of Hill Climbing methodology. The simulated annealing approach can be used to overcome the problem of the stagnation in the local Optima value. In the current study, the initial temperature is set to 2*|N|, where |N| represents the number of attributes for each dataset, and the cooling schedule is calculated as T = 0.93 * T (as adopted in [18] and [19]).

2) The proposed approach: Whenever binary optimization problems are taken into consideration, the feature selection is considered as a method which is wired to solve such problems. In the mechanism of the feature selection, the solutions are restricted to specific binary numbers namely {0, 1} values. If the KH algorithm is intended to work and compensate with this kind of feature selection method, a binary value of the version should be initially developed for this code. The solution required in this particular scenario is considered and taken as a single dimensional vector in which the length of the vector can be calculated based on the number of attributes of the original dataset. "1" or "0" represent every value in the vector (cell). Value "1" reveals that the corresponding attribute is chosen; otherwise, the value is set to "0".

Searches space diversification and exploitation for finding out the best possible solutions intensification are two criteria that are contradictory in nature. They have to be considered whenever a metaheuristic method is defined and designed [20]. Based on the criteria that have been taken over metaheuristic, it can be broadly classified into two categories: the first one can be called population-based (e.g., swarm intelligence, evolutionary algorithms) algorithms and it can be considered that these particular algorithms are exploration oriented. However, the second one is the single-solution based (e.g. local search and simulated annealing) algorithms that are exploitation oriented. A proper balance is required in all the two stated properties above for an algorithm to have a good searching performance.

Combination of powerful properties for both algorithms KH and SA can be used to produce better results. Whenever both of them are combined and collectively worked out for a particular problem, better results are obtained. This hybridization intends to improve the exploitation property of the KH algorithm. In order to enhance the exploration in the same algorithm, tournament selection mechanism is utilized rather than the random selection. Core idea of feature selection is a multi-objective optimization solution that is offered for the problem at a place where there is Herd to contradict what to use that is substantially followed and solved. The major agenda for using the selection optimization technique is to demise the values of the features that are selected to obtain maximum classification accuracy. It can be considered that the number of values that are smaller further features in action, the better the chances of the solution for more classification, the better the solution is. The use of hybridization between these two steps is global search (KH) and local search algorithm (SA). In the proposed approach, a more sophisticated hybridization model is reflected in the system. A hybridization model between the two algorithms is also considered.

a) The Low Level of KH with SA: A hybrid approach that adopts the SA to replace the refining stage in the KH is presented here. The Hybrid algorithm integrates the explorative power of the KH with the speed of an SA algorithm in refining the solutions. In the hybrid KH, the algorithm includes two modules namely the KH module and the SA module. The KH finds the optimum region and then the SA takes over to find optimum features. Combining the two will strike the right balance between local exploitation and global exploration. The results obtained from the KH module would be helpful as the initial features selected from the SA module. The SA algorithm will be applied to the refinement and generation of the final results.

$$\text{FS-low-level} = \sum_{i=n}^{i=1}\big((\text{KH} \,.\, \text{SA}) \,.\, (L)\ \text{Si},\ \text{Ni}\big) \tag{2a}$$

Where S_i is used feature, *Ni* is unused feature, *n* is number of the features and *L* is combination of KH with SA low level.

b) The Interleaved Hybridization: In this hybrid algorithm, the local approach is embedded into the KH. After each iteration, the SA adopts the best vector from the N_{pop} as the starting point. N_{pop} is updated if the locally optimized vectors show a better fitness value than those in N_{pop} and this procedure is repeated until they come to a stopping condition.

$$\text{FS-interleave-level} = \sum_{i=1}^{n}\big((\text{KH} \,.\, \text{SA}) \,.\, (\text{I})\ \text{Si},\ \text{Ni}\big) \tag{2b}$$

Where S_i is used feature, *Ni* is unused feature, *n* is the number of features and *L* is combined KH with SA Interleaved level.

c) The High Level of KH with SA: o enhance the algorithm, a one-step SA algorithm is proposed. A fresh feature selection solution is then generated by applying the KH operations, and the following process is applied to the new solution. In this algorithm, the explorative power of KH and the fine-tuning power of SA algorithms are interleaved in each iteration to obtain a high quality of features selection.

$$\text{FS-high-level} = \sum_{i=1}^{n}\big((\text{KH} \,.\, \text{SA}) \,.\, (\text{H})\ \text{Si},\ \text{Ni}\big) \tag{3}$$

Where S_i is used feature, *Ni* is unused feature, *n* is the number of features and *L* is combined KH with SA High level.

To maintain a proper balance between all particular selected features that are available as part of the solution in each of the minimum solutions and to provide the maximum accuracy for the particular feature selection, the fitness function in Eq. (4) is utilized in both KH and SA algorithms to assess search agents.

$$fitness = \alpha\gamma_R\,(D) + \beta\frac{|R|}{|N|} \tag{4}$$

Where $\gamma_R\,(D)$ represents the classification error rate of a given classier (each of three classifiers is used here). Furthermore, |R| is the cardinality of the selected subset and |N| is the total number of features in the dataset, α and β are two parameters corresponding to the importance of classification quality and subset length, $\alpha \in [0, 1]$ and β = (1-α) adopted from [21] and [22].

C. Parameter Settings

A better approach can be applied based on approaching the three classifications in the algorithm. For this particular, all datasets are divided cross validation. Finally, the cross validations are divided in the same manner as in [23] for assessment. In *K*-fold cross-validation, *K-1* folds are utilized for validation and training and the remaining folds can be used for testing purposes.

A total of *M* iterations can be applied for this process, and finally every single optimizer unit can be evaluated K*M times for each dataset. As a matter of resumption of the data used for training, the validation should be equal in size and all the parameters must be set as follows: the best results can be obtained whenever the maximum numbers of iterations are 100. The size of the population should be set to 10. A total of five iterations can be done for every algorithm and finally the random seeds must be used. All the parameters of SA are similar to those utilized in the previous subsection and can be the same as they are created in the previous section.

D. Empirical Study of the Impact of Different KH Parameters on Parameters on Convergence behaviour

This section aims to study the evolution of solution of the algorithms over generations under a number of settings of important parameters since such factors are vital for the effectiveness and precision of the algorithm. These are diverse configurations of four parameters i.e. Number of Krill's (NK) and Foraging Motion *Vf*; *NK* is the number of initial population. Under this condition, this study highlights the effect of single parameter changes. In particular, this section tests the following different scenarios as revealed in Table III.

Furthermore, every single designed case was executed twenty times with the repetition numbers set to fifty for all runs. Based on experiments, the case S7 was chosen to carry out tests in this section, the parameter is set to *NK=6*, and Foraging Motion, *Vf*, is 0.2.

TABLE. III. CONVERGENCE SCENARIOS

Scenarios	*NK*	*Vf*
S1	***1***	***0.1***
S2	***10***	***0.3***
S3	***15***	***0.4***
S4	***20***	***0.5***
S5	***30***	***0.7***
S6	***5***	***0.8***
S7	***6***	***0.2***

IV. RESULTS AND FINDINGS

Three different dataset having different characteristics in our experiments were used to obtain a fair comparative analysis and evaluation of the performance of the algorithms. The dataset collected from a famous Islamic terrorist websites, which are Alemarah1 (Islamic Emirate of Afghanistan, 2019). Islamion (Dabiq, 2019) and Tawhid(Islamic State Media,2019) websites. The dataset being tested consisted of two categories of topics, Islamic terrorists and non-Islamic terrorists. These topics of news constituted 600 'news' documents that were to be used as training and testing dataset for Alemarah1 news and Islamion. The Tawhid website used 800 'news' documents as training and testing using cross-validation methods to split training and testing. Table IV shows a summary description of the number of features in each dataset benchmarks that will be used in the experiments with the extraction method BOW.

Table V presents a summary of the results of the KNN accuracies and the number of feature results using BOW as the extraction method and PSO, HS, GA, KH optimization feature selection methods. It shows that a high accuracy of 62.8% is achieved with PSO optimization feature selection method for dataset DS3. The second rank for the best optimizations feature selection methods was the KH based on dataset DS1 with an accuracy of 60.9%. The table shows that the GA optimization feature selection method scored in DS2 with 58.9% accuracy. In addition, the minimum number of features with accuracy was related to KH in DS1 with the number of features 3157 out of 4731.

Table VI shows a summary of the results of the NB accuracies and the number of features results using BOW as the extraction method and PSO, HS, GA, KH optimization feature selection methods. It shows that the accuracies achieved with KH optimization feature selection method were the best resulting an accuracy of 67.3% for dataset DS3. The second rank for the best optimizations feature selection methods were for KH based on the dataset DS1 with an accuracy of 56.9%. The table shows that the HS optimization feature selection method in DS2 scored 54.03%. Furthermore, the best minimum number of features with accuracy was related with PSO in DS1 with the number of features 3150 out of 4731.

TABLE. IV. A SUMMARY DESCRIPTION OF THE NUMBER OF FEATURES IN EACH DOCUMENT DATASET

Document Set (DS)	**Source**	**# of webs**	**# of features**
DS1	Islamion	600	4731
DS2	Tawhid	800	7096
DS3	Alemarah1 news	600	4636

TABLE. V. THE KNN ACCURACIES AND NUMBER OF FEATURES RESULTS USING BOW AS EXTRACTION METHOD AND OPTIMIZATION FEATURE SELECTION METHOD

DS		***PSO***		***HS***		***GA***		***KH***	
	Original # of features	*# of features*	*Accuracy*	*# of features*	*Accuracy*	*# of features*	*Accuracy*	*# of features*	*Accuracy*
DS1	***4731***	***3654***	***60.46***	***3541***	***59.3***	***3832***	***59.5***	***3157***	***60.9***
DS2	***7096***	***6378***	***56.9***	***6921***	***57.21***	***6835***	***58.9***	***6457***	***57.6***
DS3	***4636***	***3256***	***62.8***	***3025***	***60.3***	***3293***	***60.9***	***3560***	***61.74***

TABLE. VI. THE NB ACCURACIES AND NUMBER OF FEATURES RESULTS USING BOW AS EXTRACTION METHOD AND OPTIMIZATION FEATURE SELECTION METHOD

DS		PSO		HS		GA		KH	
	Original # of features	*# of features*	*Accuracy*	*# of features*	*Accuracy*	*# of features*	*Accuracy*	*# of features*	*Accuracy*
DS1	4731	3150	54.35	3298	55	3818	55.2	3880	56.9
DS2	7096	5763	53.98	5643	54.03	4980	53.9	5870	53.9
DS3	4636	3653	66.9	3720	66.89	3911	67	3795	67.3

Table VII shows a summary of the results of the SVM accuracies and the number of features results using BOW as extraction method and PSO, HS, GA, KH optimization feature selection methods. It shows that the best accuracy was achieved with KH optimization feature selection methods equalling 71.9% for dataset DS2. The second rank for the best optimizations feature selection methods was KH based on dataset DS3 with an accuracy of 65.1%. The table shows that the KH optimization feature selection method in DS1 scored an accuracy of 59.3%. In addition, the best minimum number of features with accuracy was related to KH in DS1 with the number of features 3126 out of 4731.

Table VIII shows a summary of the results of the SA accuracy and the number of features results using BOW as extraction method and three classifiers algorithm. It shows that the SVM classifier yielded the best accuracy equalling to 71.13% for dataset DS2. The second rank for the best classifier was for NB based on dataset DS3 with an accuracy of 66%. The table shows that the KNN classifier in DS1 scored 60.41%. In addition, the best minimum number of features with accuracy was related to KNN and NB in DS1 and DS3 with number of features 2943 out of 4731 and 3420 out of 4636. The best result was achieved in dataset DS2; that is 5720 out of 7096, with KNN, but it does not offer a high accuracy. For example, while the minimum of number of features in DS2 was 5720 out of 4731 using KNN; the best accuracy was obtained when using SVM with number of features of 5796 which is higher than that of KNN. The best number of features in terms of accuracy was in DS1 using KNN.

TABLE. VII. THE SVM ACCURACIES AND NUMBER OF FEATURES RESULTS USING BOW AS EXTRACTION METHOD AND OPTIMIZATION FEATURE SELECTION METHOD

DS		PSO		HS		GA		KH	
	Original # of features	*# of features*	*Accuracy*	*# of features*	*Accuracy*	*# of features*	*Accuracy*	*# of features*	*Accuracy*
DS1	4731	4016	55.95	3951	58.9	3852	59.34	3126	59.3
DS2	7096	6128	70.94	6629	71.31	6214	70.59	6721	71.9
DS3	4636	3601	63.67	4300	64.22	3746	63.22	3529	65.1

TABLE. VIII. THE SA ACCURACIES AND NUMBER OF FEATURES RESULTS USING BOW AS EXTRACTION METHOD ON THE BENCHMARK DATASET

DS		SVM		NB		KNN	
	Original # of features	*New # of features*	*Accuracy*	*New # of features*	*Accuracy*	*New # of features*	*Accuracy*
DS1	4731	3015	57	3205	54.92	2943	60.41
DS2	7096	5796	71.13	5891	52.76	5720	55.95
DS3	4636	3583	62.8	3420	66	3509	60.17

Based on Tables V to VIII, the best results were achieved in SVM with KH with a score of 70.9% and the number of features 6721 out of 7096. In general, the KH is better than other optimizations as feature selection using SVM, but not with all results. On the other side, the SVM is better than NB and NB is better than KNN. The next section evaluates the combination of the power of the proposed KH approach and the power of SA as a feature selection.

A. The Low Level of Krill Herd with Simulated Annealing

Table IX provides a summary of the results of the three classifiers accuracies and the number of feature results using BOW as an extraction method using the low level of KH with SA optimization feature selection methods. It shows that the accuracies achieved with SVM were the best with an accuracy of 72.6% for the dataset DS2. The second rank was to NB based on the dataset DS3 with an accuracy of 68.42%. The table also shows that the SVM in DS1 scored 59.86%. In addition, the best minimum number of features in terms of accuracy was related to SVM in DS1 with a number of features 2960 out of 4731.

B. The Interleaved of Krill Herd with Simulated Annealing

Table X provides a summary of the results of accuracies of the three classifiers and the number of feature results using BOW as the extraction method and using interleaved hybridization optimization as feature selection method. It shows that the highest accuracy, 73.01%, is achieved with SVM for dataset DS2. The second and third ranks were for SVM based on dataset DS3 with 71.98% and DS1 with 60.8% accuracies respectively. In addition, the best minimum number of features in terms of accuracy was related to SVM in DS3 with a number of features 2397 out of 4636.

TABLE. IX. THE LOW LEVEL OF KH WITH SA

DS		SVM		NB		KNN	
Dataset	*Original # of features*	*# of features*	*Accuracy*	*# of features*	*Accuracy*	*# of features*	*Accuracy*
DS1	4731	2458	60.8	3019	57.93	2969	71.2
DS2	7096	4389	73.01	5211	55.68	5701	59.1
DS3	4636	2397	71.98	3102	70.1	3114	70.9

TABLE. X. THE INTERLEAVED HYBRID

DS		SVM		NB		KNN	
	Original # of features	*# of features*	*Accuracy*	*# of features*	*Accuracy*	*# of features*	*Accuracy*
DS1	4731	2458	60.8	3019	57.93	2969	71.2
DS2	7096	4389	73.01	5211	55.68	5701	59.1
DS3	4636	2397	71.98	3102	70.1	3114	70.9

C. The High Level of Krill Herd with Simulated Annealing

Table XI presents a summary of the results of the three classifiers accuracies and the number of features results using BOW as an extraction method using a high level of KH with SA optimization feature selection methods. It shows that an accuracy of 72.6% was achieved with SVM for dataset DS2. The SVM based method on the dataset DS3 ranked second with an accuracy of 66.2%. The table shows that KNN in DS1 scored 60.84%. In addition, the best minimum number of features in terms of accuracy was related to SVM in DS1 with a number of features 3006 out of 4731.

Table XII provides a summary of the results for the six optimizations as feature selections and the number of features results using BOW as an extraction method using high SVM methods. It shows that the minimum of feature selected was better when using interleave KH with SA.

TABLE. XI. THE HIGH LEVEL OF KH WITH SA

DS		SVM		NB		KNN	
	Original # of features	*# of features*	*Accuracy*	*# of features*	*Accuracy*	*# of features*	*Accuracy*
DS1	4731	3006	59.86	3725	57.6	3097	60.84
DS2	7096	6219	72.6	5490	54.1	6237	58.75
DS3	4636	3491	66.2	3915	68.42	3397	60.91

TABLE. XII. SUMMARY OF THE NEW NUMBER OF FEATURES USING SVM CLASSIFIER

		interleave	KH	SA	GA	PSO	HS
Data set	*Original # of features*	*New # of features*	*New # of features*	*New # of features*	*New # of features*	*New # of features*	*New # of features*
DS1	4731	2458	3126	3015	3852	4016	3951
DS2	7096	4389	6721	5796	6214	6128	6629
DS3	4636	2397	3529	3583	3746	3601	4300

V. CONCLUSION

The major portions that are covered in this particular study are the findings of all the near optimal features, the selection of all the optimal features. With respect to the fitness function, which is given in the criteria, it is imperative that all the values of the features are available in a specific classifier for different classes and category types. Considering all algorithms, it is shown that SVM produces the best performance and NB outperforms KNN. Based on the behaviour of all the classifiers that were obtained, the meta-heuristic such as the Harmony Search feature selection is very helpful to find out and fill the gaps of the problem of misclassification. The reaction for the algorithm HS is depicted in this study and based on selecting the fitness function for evaluation, it is concluded that the high level of combining KH with SA gives the worst performance compared to the low level of combining KH with SA and interleaves of combining KH with the SA proposed feature selection. Thus, this study proposes three combinations of combining KH with SA algorithm to address this problem. The impact of NK and Vf KH parameters is tested, and the empirical studies demonstrate that the NK parameter is set to 6, and the Vf is 0.2. The first finding that considers the proposed KH was better than HS as the feature selection, and the interleave of combined KH with SA show the best performance. After looking at the observations, and with the aim to find out the best advantage of KH, an extension of the KH algorithm is done with the help of the SA algorithm. It is concluded that the best performance is achieved when KH is interleaved with SA.

This study suggests some directions for future research. Upcoming studies should try to find out the results for the new stages that are available in the extraction methods called the pragmatic of 'Bag-of-Narratives', which focus on conweb-aware and intent-driven methods. These pragmatic curves play an important role for analysing tasks such as sentiment analysis known as a concept in which a negative connotation is generally taken into account (e.g., small seat, might turn out to be positive, if the intent is for an infant to be safely seated in it. The current study has some limitations, one important of which is the difficulty in assessing or evaluating the accurate performance of the parameters of KH. Therefore, future researches could attempt to develop a new way to find the best parameters settings.

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Knowledge Discovery based Framework for Enhancing the House of Quality

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***Abstract*—Mining techniques proved to have a successful impact in different fields for many targets; one of these targets is to gain customers' satisfaction through enhancing the products' quality according to the voice of these customers. This research proposes a framework that is based on mining techniques and adopted Saaty method targeting to gain the customers' satisfaction and consequently a competitive advantage in the real estate market. The proposed framework is applied during the design phase of a real estate residential building project as an improvement tool to design the building according to the customers' requirements representing the voice of customers (VOC). The proposed Saaty method adaptation increased the number of the consistent sample which was incorrectly excluded using the traditional Saaty method. Saaty method adaptation has succeeded in enhancing the house of quality (HOQ) by achieving the consistent technical customers' requirements for residential buildings, while customers' segmentation succeeded in focusing on the homogeneous grouping of customers.**

Keywords*—Knowledge discovery; mining techniques; customer segmentation; Saaty's method; customer satisfaction

I. Introduction

Customers' satisfaction is one of the continuous vital targets in business fields [1]. It is a fact that different researches have focused on customer satisfaction [2] either directly [3] or through other directions such as the process adaptation [4] [5] [6].

No doubt that VOC that represents the customers' requirements is a vital factor that should be considered by any service or product firm to compete in the market against competitors and consequently to have a competitive advantage. However, as customers have different personality, their preferences will naturally differ [7]. As mapping customers to residents is one of the keys for successful real estate business, therefore, identifying the suitable customer to each territory is one of the current research objectives. To achieve this target, these presented researches have highlighted a focus on the Quality Function Deployment (QFD) for enhancing the HOQ through considering the VOC.

Therefore, two perspectives should be considered for satisfying this variation and maintain the product quality as well. The first perspective is segmenting the customers according to their preferences, and the second perspective is to determine the consistency of these requirements. Different approaches have applied clustering mining techniques for segmenting the business customers [8] [9] [10], which consequently lead the firm to focus on the defined set of customers for achieving their need with ensuring their interestingness in the resident.

Focusing on the real state field, QFD achieved by focusing on the HOQ, the first phase of QFD, to integrate and analyze VOC before the design phase. QFD was first introduced in 1960s, it was used by several companies but did not draw much attention [11]. Few years later, QFD was implemented in Mitsubishi Heavy Industries, followed by Toyota Japan. Later QFD entered the US in General Motors, Chrysler, Digital Equipment, Hewlett-Packard, AT&T, Procter and Gamble, and Baxter Healthcare.

This remaining of the research is as follows: section 2 represents the background describing QFD, HOQ, and advantage of using HOQ, importance of design phase, competitive advantage, and customer satisfaction. Section 3 introduces the previous research which applied the traditional method in HOQ, as well as Saaty Model with highlighting the customer segmentation research in different fields in section 4. Section 5 proposes the customers' segmentation framework based on cluster mining technique and the Saaty method adaptation. Moreover, section 6 presents the case study, calculation, and final output results. Section 7 introduces customer evaluation on the proposed work before and after implementing the proposed HOQ approach. Finally, section 8 is the conclusion and the future work.

II. House of Quality (HOQ)

House of quality is the first phase of the QFD matrices, it is a subset of the QFD [12]. It is a diagram in a shape of a house with five walls [13] the left wall emphasizes the customer acquirements [14].

The focus of presented research is on the left walls which include the customers' requirements representing the VOC. This research enhances the left wall impact on the design phase by determining the consistent customers' requirements with focusing on their importance level. Consistent VOC is determined by the adopted Saaty method while the importance rate is determined through applying mining techniques.

III. Literature Review for HOQ Evaluation Models

Decision Quality has been considered in many research for many fields such as in [15] [16]. Focusing on HOQ in residential field, Olewnik and Lewis (2008) discuss in their research that HOQ is a supportive tool for decision making

which can be illustrated as a diagram with five walls where the left wall illustrates the VOC. Different methods are proposed for achieving the VOC, traditionally, a scale with a determined rate is used for the requirement evaluation [13]. Although the traditional method is widely used in a high range of applications and projects [14] [17], however, there results were obtained without excluding any customer sample which was a focus for many researchers due to its impact on the results' accuracy. Karsak and his colleagues in [11] used Saaty method in obtaining importance weighting in the HOQ, the results concluded that they were more accurate than the traditional method due to excluding the non-consistent customer samples in the HOQ calculations. Another research by Johny and Wong [18] which concluded that the examination of relationships was limited to those between the building system and selection criteria with the use of the AHP. Applying AHP (Saaty's method) for determining the consistency of the customers' evaluation can be illustrated in the following steps:

1) Matrix of requirements' comparison: Matrix of Requirements (MR) includes N * N items where N is the number of requirements. The matrix is built for each customer (MRcustomer i) which includes the relation between the requirements according to the customer preferred level, the preference varies from 1 representing the least preferred to 9 representing the most preferred.

Considering the preference of requirement x over y is 2/9, then:

MRx,y = 2 and MR y,x = 2/9 = 0.22

2) Determine Eigen Vector matrix (EV): In this step, for each customer, Eigen vector is determined for each of his requirements as follows:

- Determine the product of each requirement preferences (Px) as follows:

$$P_x = \prod_{y=1}^{n} MR_{xy}$$

- Determine the total product for all requirements as follows:

$$P_{Total} = \sum_{x=1}^{n} P_x$$

- Eigen vector is determined by multiplying the preference value of each requirement over the other requirements divided by the summation of all products for all the requirements as follows:

$$Eigen\ vector_x = \frac{P_x}{P_{Total}}$$

$$\mathbf{EV}_{Customer\ i} = [Eigen\ vector_i] \quad where\ i = \{0,1,2, \dots 10\}$$

3) Determining the eigen value Matrix (Mλ): Eigen value matrix is a one column matrix representing the value of λ for each requirement, it is determined as follows:

$$\mathbf{M\lambda}_{Customer\ i} = \quad MR_{Customer\ i} \times \mathbf{EV}_{Customer\ i}$$

4) Determining the Consistency Index (C.I): According to the traditional Saaty method, The consistency index (C.I) considers the maximum value of λ (λmax) for each customer i that exists in $M\lambda_{\text{Customer i}}$ as follows:

$$C.I_{customer\ i} = (\lambda_{max} - n)\ (n-1)$$

Where n is the number of requirements

5) Determining the Consistency Ratio (C.R): Finally, Consistency Ratio for customer i (C.R customer i) is calculated as follows:

$$CR_{customer\ i} = C.I_{customer\ i} \times \frac{1}{m}$$

Where m is a constant which value depends on the number of requirements [19].

IV. Lierature Review for Customer Segmentation based on Clustering Mining Techniques

Traditionally, Customer segmentation is a significant method for providing a homogenous group while focusing on the customers' needs versus the market offers, however, customer segmentation can be performed by different criteria [20]. It could be based on their value, their lifetime value, or their customer need-based segmentation [21] [22]. Recently, firms are sharing the market in a critical environment in which it is a vital task to identify the customers' preferences and consequently determine the correct profitable decision [23]. Customers' segmentation supports driving the differentiation strategy as it is considered in this research a key for success for market initiative to customer/product matching.

In this direction, customer relationship management scope has been adopted to include the discrimination of customers' preferences. Including the customer life trend and assessing his current situation would be very efficient in predicting his preferences. Recently, data mining field has proved its effectiveness in the commercial field. Discovering interesting patterns such as correlations between stakeholders [20], patterns [24] and others [8] [25], could be different targets to use commercially [26]. Therefore, applying mining techniques could be very efficient for this target with respect to the available data [6]. Mining field offers efficient techniques including k-mean, statistics, neural networks, and others [27] [28]. Conducting the segmentation process through customers' behavioral approach especially in residential market can clearly illustrate the tacit market.

Customers' segmentation is considered an effective step [6] [9] [29], yet, selecting the suitable method for segmentation is also a target that should be focused on in order to reach a satisfying result [3] [21] [30]. Traditionally, mathematical methods are applied, however, it could not consider the correlations and other relations between the entities [31]. According to many research such as in [23] [32] [33], a focus on the customer value is a vital key rather than the customers' homogenous rate [34] [35].

Different approaches have been proposed which apply data mining techniques for CRM. A research in [32] proposed an approach for customer segmentation focusing on the customer behaviors while another research in [36] proposed a prediction

model to predict the return of investment for the retention activities. While decision tree is one of the applied techniques as in [37], however, it is crucial as many decision could be a choice as the decision tree can provide too many instances as well as its large computation time which is one of the drawbacks in another mining technique named Neural Network (NN). While k-means is one of the traditional approaches for clustering [38], however, it also has a considerable drawbacks. In this research follows applying the enhanced k-means algorithm that is proposed in [10] which overcome the traditional k-means drawbacks and provide other advantages in the computation as well as the output trustiness.

V. Proposed Customer Segmentation Framework based on Adopting Saaty Method

Implementing data in the HOQ from customer samples was filtered to consider the consistent samples only. This was achieved by implementing Saaty method in all customers, the customer that turn consistent, their results have been implemented in HOQ. In this research, an adaptation has been recommended to Saaty method to gain better results, this adaptation has been applied and proved to gain more accurate results for the HOQ.

The results obtained from the HOQ, depend on the priorities of the customers' requirements and their preferences of these requirements as well as their value in the firm. These results considered in the design phase of the building. Implementing VOC in the residential designs leads the firm to gain a leading position in the market by surpassing customer expectations.

VI. Key Steps in the Proposed Framework

The proposed framework includes two main key steps for reaching the required target. They are successful customer segmentation and applying the adopted Saaty method on the customers' data.

VII. Apply Knowledge Discovery for Customer Segmentation

Earlier, K-means algorithm has been applied for successful segmentation, however, different enhancements have been proposed for higher accuracy. A research in [10] proved an enhancement by changing the centroid point from random point to the center point. More research in applied k-means approach by using median calculation, or metoid calculation. Each of the previously mentioned research has proved the accuracy enhancement.

This research follows the enhancement in k-means which is applied in [10] with integrating the enhancement approach. The main enhancements in [10] is to adopt the random selected point to the centroid point. This enhancement has proved to achieve more accurate clustering results, the enhancement included to minimize the computation complexity by determining a suitable threshold and assign the element to its first matching class according to the determined threshold. This approach has proved its effectiveness in the biomedical field. As it was one of the future research to investigate new fields, therefore, in this research, we aim to prove its applicability in a different field which is the residential market. The following is the adopted formalization for enhanced k-means algorithm steps which is applied for for customers' segmentation phase

- Determine the set of clusters S = {S_1, S_2, …. S_i} where I is the number of clusters
- Determine the corresponding set of center points C {C_1, C_2, …. C_i}
- Repeat
- Determine the distance set Dij of data point j and the centers of all the clusters
- Determine the minimum element in Dij between the data point j and the centers of the clusters i
- Determine the new mean for all clusters i
- Until no elements requires testing

A. Adopting Saaty's Method

Calculation of C.I using Saaty's method by using the maximum value of λ from all λ values turned to be that λmax could be an extreme value and the otherλ's are in range this will result that C.R will turn to be inconsistent due to that we have one extreme value and the other λ's that are in range if used to calculate C.R the result might turn to be consistent. This extreme value will cause decisions taken to refuse samples in calculations due to the inconsistency. This extreme value will lead to inaccurate decisions to exclude vital samples.

The proposed enhancement for Saaty's method is including other λ calculations to λmax, they are λmean and λmedian. Therefore the sample is decided to be consistent and is used in calculations of eigenvector and is used in the importance weight of HOQ if it had at least two of the three λ measures to be < 0.4. This approach in calculating three λ measures is performed to avoid issues with extreme values.

To obtain correct data in the calculation obtaining appropriate numbers or λ's is mandatory. Obtaining appropriate data is reached by measuring the central tendency of the numbers (λ). Central tendency is a numeric value that measures the middle value of data set and the spreading data around it. Central tendency is performed by measuring the mean, median, and mode, each of these measures is calculated differently, and the measure that is used best, depends upon the situation. This approach has been considered in this research by including mean and median in measuringλ. Mode measure is the value that appears most frequently or is repeated several times, therefore mode measure was not applicable in this research due to that it is hard to obtain repetitive numbers.

VIII. Proposed Framework Illustration

Fig. 1 illustrates the proposed framework phase which reveals the main applied steps to reach the required target. Section 6 presents the experimental study in which each step is discussed and applied in details.

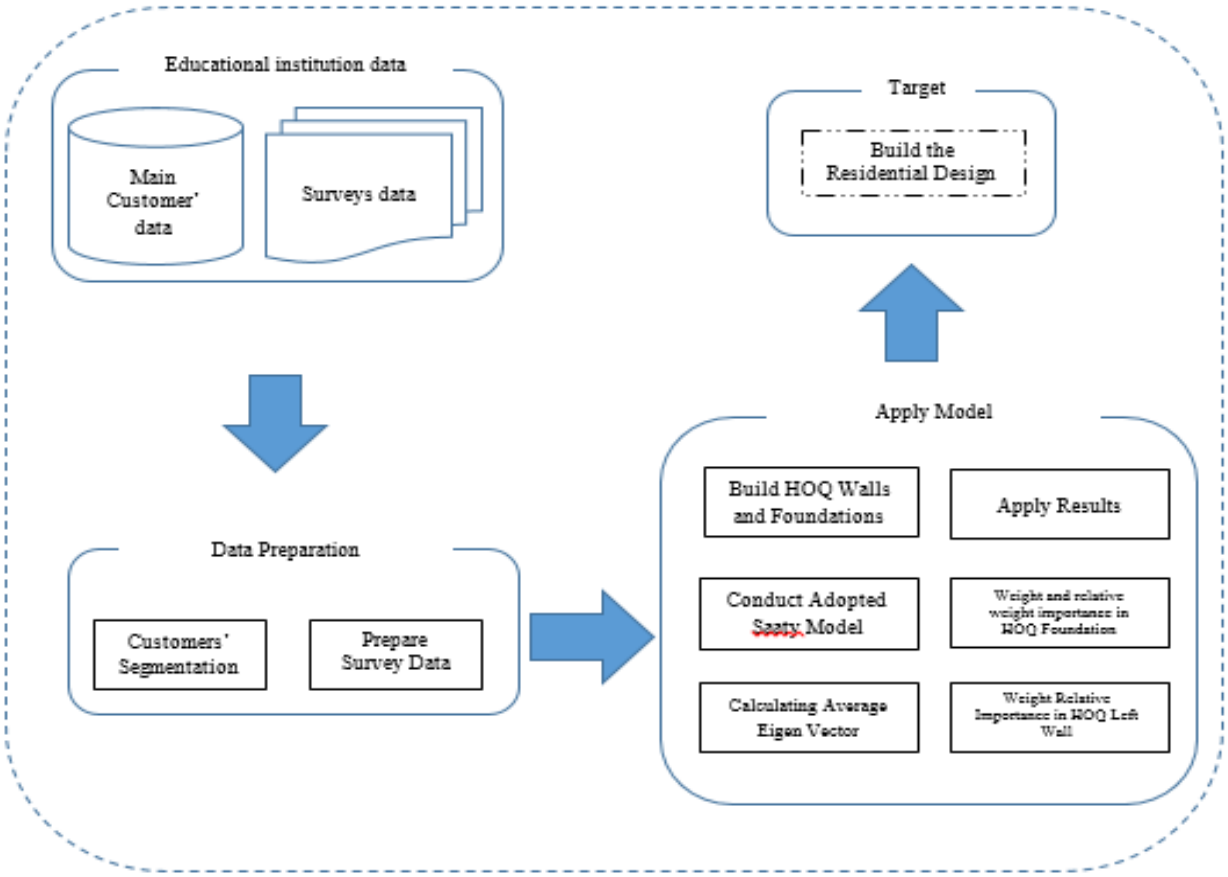

Fig. 1. Knowledge Discovery Based-Proposed Framework.

IX. Experimental Study

Most of the research apply the experimental results using a bench mark dataset such as in [39] and [40], others used a real dataset such as in [41], [42] and [43].

One of the main strength factors in this research that the proposed framework has been applied on a real case. The proposed framework has been considered before design phase on residential buildings using the proposed adaptation of Saaty method. The experiment was performed on 'Abyat' which is one of the real state firms in the residential Egyptian market. The firm is located in the capital city of Cairo, in the province of Mokattam. The firm's targets the B- to B+ customer segment which are the medium value customers that represent around 40% of the market.

The target of customers' segmentation is to focus on a determined segment targeting to develop a real residential to this selected customers. Selecting a determined customers' segment is a positive step towards consistent requirements which is a positive support to the proposed Saaty method enhancement to ensure effective results.

Abyat Company targeted to build nine buildings in Mokattam area. The aim was to select from eight to fourteen customers of its customers' pool, apply the research phases on these customers' data and requirements, and then build the residential design according to these requirements. The experiment went all through the phases starting from selecting the customers, build the residential design, and build the residential according to the results performed from this research. Furthermore, a review has been developed to gather the customers' response and the results of this review is presented in this study. The study presents the old residential design and new design according to the recommendations of this research. Then the study presents the approval of the Egyptian government for the residential building and photos for the residential in its final implementation stage.

X. Customers' Segmentation and Requirements' Determination

Collecting customers' requirements were performed by interviewing sales persons who have direct contacts with customers to collect the required customers' data. According to the sales persons, the customers' requirements have been determined which is required as a preparatory step for the customers' segmentation. The experiment collected data for 120 customers, then Enhanced k-means algorithm is then applied. According to the limited number of customers that were required for the experiment, a segment with ten customers was selected [44]. Other segments included either more than 14 customers or less than eight customers which were out of the research limitation. Table 1 presents the internal and external requirements that are collected from the customers' segments.

TABLE. I. VOC REQUIREMENTS FOR RESIDENTIAL BUILDINGS

Internal Requirements	1.	Bathroom in master bed room
	2.	Large kitchen that fits all appliances
	3.	Two extra rooms, so total of rooms would be three rooms
	4.	Reception area fits more than two units (minimum two)
	5.	Large bathroom for whole family use
	6.	Apartment on front view elevation not back or side view elevation
External Requirements	7.	Elevator
	8.	Attractive entrance appearance
	9.	Attractive elevation appearance
	10.	Garage for cars

XI. APPLY ADAPTIVE SAATY METHOD AND BUILD THE HOUSE OF QUALITY (HOQ)

In this process the HOQ was implemented with the data that has been collected, the left wall of the HOQ is the VOC, the upper part of HOQ is the technical specifications that represent the needs of customer but in technical specification made by experts. In this step the implementation of data in the HOQ left wall, right wall, roof top, middle house, and foundation, without the weight of importance in the left wall which will be calculated using the proposed improvement of Saaty method.

The following is a sample of applying the proposed adaptation on one of the customers' data (Customer 1). Table 2 presents MRcustomer I while table 3 illustrates the values of P and Eigen vector for customer I preferences. Table 4 illustrates the Mλ, Moreover, table 5 presents C.I and C.R for customer 1 to determine the consistency of his preferences.

According to table 5, the requirements of customer 1 is consistent, due to that two of theλ's turn to be consistent, this sample customer data will be taken in the calculation of the HOQ. According to the Customers' requirements, Saaty's matrix is determined for each customer. Table 6 presents a sample of Saaty's matrix for 3 customers as an example including λmax, λmedian, and λmean. The table data shows that depending on λmax only will lead to inaccurate decision considering the requirements consistency while considering the three measures leads to including customers in a more stable approach. Using three different eigenvalues (λ) three C.R were calculated for each of the ten customer, due to the three different values of λ, as described before in the improvement of Saaty's method, the samples that were accepted to be consistent is the samples with at least two of three consistent C.R's, in this case only four sample (sample 1,2,4 and 7) turn to be consistent, and these are the samples that will be taken in all calculations.

TABLE. II. MR FOR CUSTOMER 1

	1	2	3	4	5	6	7	8	9	10
1	1.00	0.20	0.11	0.14	0.14	0.11	0.33	0.11	0.11	5.00
2	5.00	1.00	0.20	0.14	3.00	0.11	3.00	0.14	0.14	7.00
3	9.00	5.00	1.00	0.20	5.00	0.11	5.00	0.33	0.33	9.00
4	7.00	7.00	5.00	1.00	0.14	0.11	5.00	0.33	0.33	7.00
5	7.00	0.33	0.20	7.00	1.00	0.11	0.33	0.14	0.14	7.00
6	9.00	9.00	9.00	9.00	9.00	1.00	9.00	9.00	9.00	9.00
7	3.00	0.33	0.20	0.20	3.00	0.11	1.00	0.20	0.20	7.00
8	9.00	7.00	3.00	3.00	7.00	0.11	5.00	1.00	0.33	7.00
9	9.00	7.00	3.00	3.00	7.00	0.11	5.00	3.00	1.00	7.00
10	0.20	0.14	0.11	0.14	0.14	0.11	0.14	0.14	0.14	1.00

TABLE. III. CALCULATION OF EIGEN VECTOR FOR CUSTOMER 1

	1	2	3	4	5	6	7	8	9	10	Product	Eigen Vector
1	1.00	0.20	0.11	0.14	0.14	0.11	0.33	0.11	0.11	5.00	0.25	0.01
2	5.00	1.00	0.20	0.14	3.00	0.11	3.00	0.14	0.14	7.00	0.68	0.04
3	9.00	5.00	1.00	0.20	5.00	0.11	5.00	0.33	0.33	9.00	1.38	0.08
4	7.00	7.00	5.00	1.00	0.14	0.11	5.00	0.33	0.33	7.00	1.31	0.07
5	7.00	0.33	0.20	7.00	1.00	0.11	0.33	0.14	0.14	7.00	0.67	0.04
6	9.00	9.00	9.00	9.00	9.00	1.00	9.00	9.00	9.00	9.00	7.22	0.41
7	3.00	0.33	0.20	0.20	3.00	0.11	1.00	0.20	0.20	7.00	0.57	0.03
8	9.00	7.00	3.00	3.00	7.00	0.11	5.00	1.00	0.33	7.00	2.35	0.13
9	9.00	7.00	3.00	3.00	7.00	0.11	5.00	3.00	1.00	7.00	2.93	0.17
10	0.20	0.14	0.11	0.14	0.14	0.11	0.14	0.14	0.14	1.00	0.17	0.01
											17.53	

TABLE. IV. CUSTOMER 1 λ VALUES

λ	1.	12.92
	2.	13.09
	3.	12.75
	4.	16.33
	5.	22.60
	6.	13.84
	7.	12.50
	8.	11.89
	9.	11.81
	10.	14.02
Total	11.	141.74

TABLE. V. CONSISTENCY OF CUSTOMER 1

		λmax	λmean	λmedian
Customer 1	λ	22.6	14.17	13.01
	C.I	1.4	0.46	0.33
	C.R	0.94	0.31	0.22
	Consistency	Non-Const.	Const.	Const.

TABLE. VI. CONSISTENCY OF 3 CUSTOMERS' SAMPLE WITH THREE λ RESULTS

		λmax	**λmean**	**λmedian**	**Decision**
Customer 1	λ	22.6	14.17	13.01	Consistent
	C.I	1.4	0.46	0.33	
	C.R	0.94	0.31	0.22	
	Consistency	Not-Const.	Const.	Const.	
Customer 2	λ	16.09	14.11	14.3	Consistent
	C.I	0.68	0.46	0.48	
	C.R	0.45	0.31	0.32	
	Consistency	Not-Const.	Const.	Const.	
Customer 3	λ	22.88	15.89	14.69	Not Consistent
	C.I	1.43	0.65	0.52	
	C.R	0.96	0.44	0.35	
	Consistency	Not-Const.	Not-Const.	Const.	

A new average matrix is formed from a ten consistent samples set, by obtaining the average matrix with the calculation of the eigenvector and implements the left wall of the HOQ in the weight importance column and therefore continuing the HOQ calculations. The importance weight in the HOQ foundation identifies the most important technical feature to the least important. Importance weight in the foundation is calculated by taking every technical column multiplying first need by the relative correlation in the row and adding the next requirement after multiplying it by its relative correlation.

For example, the importance weight of the third technical requirement apartment area between 110 and 150 is calculated as follows.

Weight importance = [(0.1*9) +(0.1*9) +(0.2*9) +(0.1*9) +(0.1*9) +(0.2*1)] *100= 487.6

Relative weight is calculated by dividing importance weight by the total importance weight and multiplying it by 100 as follows:

$$\text{Relative Weight} = \left(\frac{487.6}{48+77.3+487.6+156.5+113.8+60.4+67.3+31.8}\right) * 100 = 46.8\%$$

XII. APPLY RESULTS

The final result obtained is shown in fig 3 while table 7 shows the ranking of the most important technical specifications that the design team needs to follow.

According to the experiment results, the residential design has been changed from fig. 2, fig. 3 and fig. 4 according to the technical requirements updates.

TABLE. VII. RANKING OF TECHNICAL SPECIFICATIONS

	Technical Specification	% Importance
1	Apartment area between 110m to 150m	46.8
2	Apartment rotation at main elevation view	15.0
3	Elevators stop at all floors from garage to roof	10.9
4	Increase are of kitchen to fit all appliances	7.4
5	Modern style elevations and cheerful colors	6.5
6	Marble and decoration in entrance of building	5.8
7	Increase area of master room to fit bathroom	4.6
8	Identify for each car a specific place in garage	3

XIII. EVALUATION

After applying the results from HOQ, a survey has been applied to measure the customer satisfaction after the design updates. The customers were asked to give their feedback with a scale from 1 to 5 (where 1 is not satisfied and 5 is extremely satisfied) to compare their opinion for the first residential building design, with the new design that was obtained from the HOQ. The evaluation results are shown in table 8 which proves the higher satisfaction level using the new design.

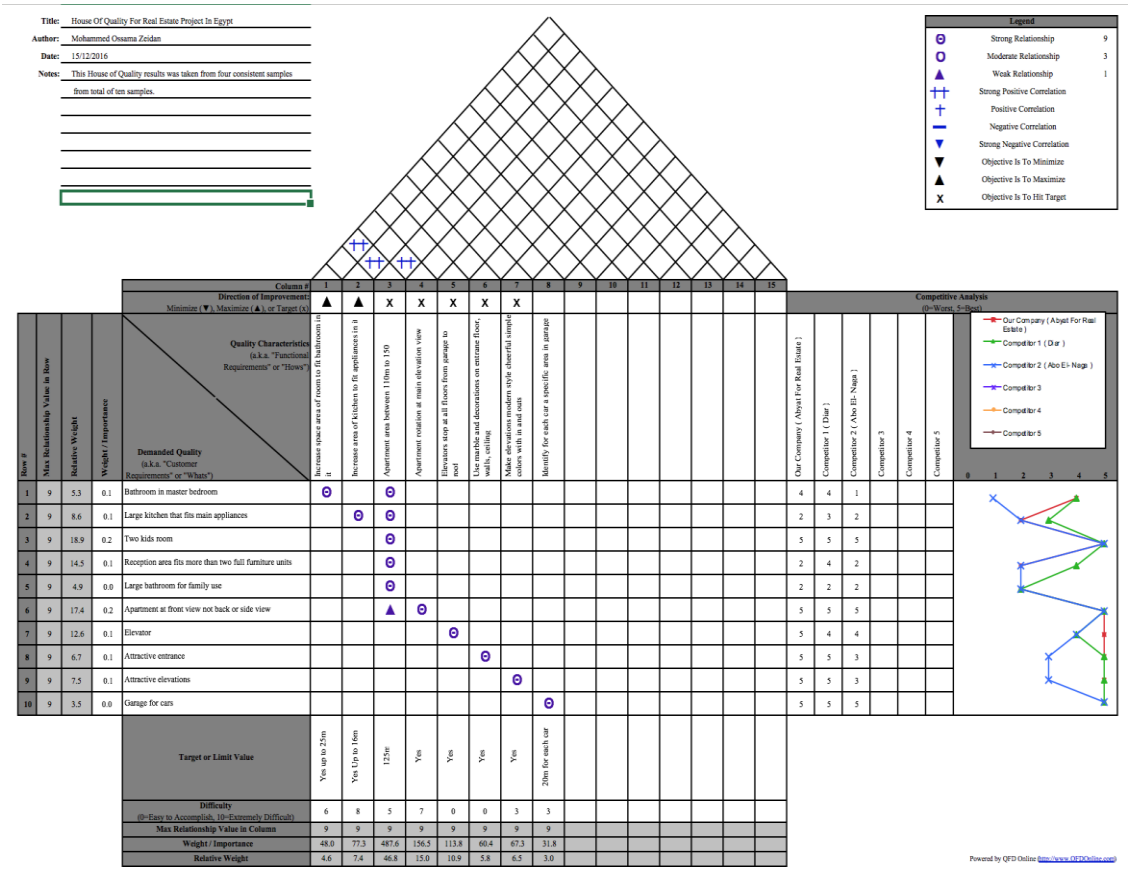

Fig. 2. House of Quality.

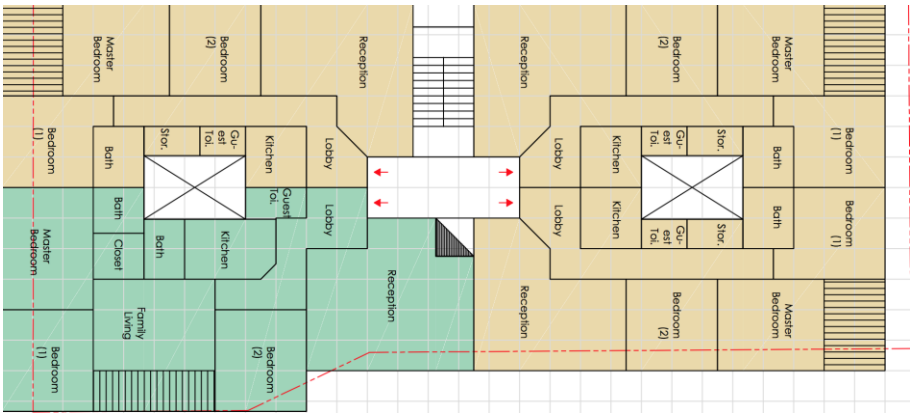

Fig. 3. Design of a Residential Apartment before House of Quality Results.

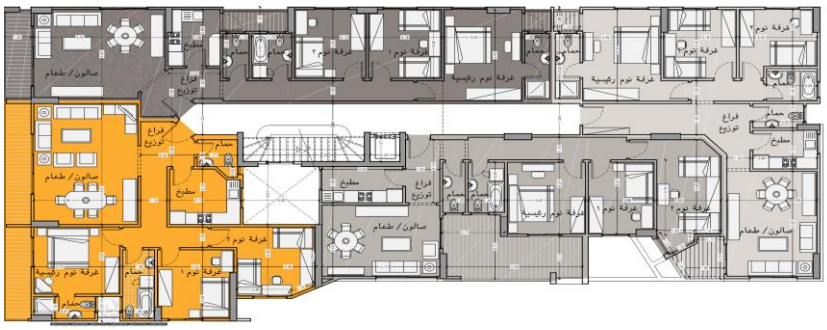

Fig. 4. Design of a Residential Apartment after Implementing House of Quality Result.

TABLE. VIII. CUSTOMER EVALUATION BEFORE AND AFTER HOQ

Customer Needs	Residential Building Before VOC	Residential Building After VOC
Bathroom in master bedroom	3	5
Large kitchen that fits main appliances	2	3
Two kids room	3	5
Reception area fits more than two full furniture units	3	3
Large bathroom for family use	2	3
Apartment at front view not back or side view	2	5
Elevator	5	5
Attractive entrance	4	4
Attractive elevations	4	5
Garage for cars	3	4
How Are You Satisfied with old and new design	3	5

XIV. RESEARCH SIGNIFICANCE

Implementing the market with a product made by the VOC helped the organization turnover to become faster during the time period of the project. The main contribution in the research can be summarized in two main points: the successful customer segmentation which is performed by applying the enhanced k-means algorithm and the customer samples requirements consistency by considering three measures in the adaptive Saaty method which are λmedian, λmax and λmean. According to the experiment results, applying customers' segmentation supported the proposed framework in gathering the most related customer in one resident, and including customers' requirements that could be previously excluded when using the traditional Saaty method.

XV. CONCLUSION AND FUTURE RESEARCH

House of quality is a valuable and flexible six sigma tool, as it was used on several products and services which was also very useful in real estate. House of quality helped the firm's architectural engineers to improve their design feature and specifications as per customer requirements, which leads the company to gain a competitive advantage in the market and customer's satisfaction. The importance of the results obtained from the house of quality ranked the important features of the customer from the most important to the least, which lead that the design was developed by the most important features the customer required to gain in his residential building.

The proposed approach has been applied and a real resident has been designed. The customers' satisfaction is measured using a survey which highlighted a higher satisfaction level with the new design. Currently, the resident is under construction in the real world in Mokattam area in Egypt.

The authors selected the residential field as information systems rarely applied in this field. Future directions is to confirm that the proposed approach is not limited to be applied in the residential field, the authors have a challenge in next research which is to prove the positive impact of the proposed approach on different fields. Another direction is investigating other data mining techniques to increase the approach accuracy. The authors also highlighted the necessity for the collaboration of different techniques which have different nature, one is heuristic approach and the other is a statistical approach.

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Convolutional Neural Network for Diagnosing Skin Cancer

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***Abstract*—Diagnosis of melanoma (skin cancer disease) is a challenging task in medical science field due to the amount and nature of the data. Skin cancer datasets are usually comes in different format and shapes including medical images, hence, data require tremendous efforts for preprocessing before the auto-diagnostic task itself. In this work, deep learning (convolutional neural network) is used to build a computer model for predicting new cases of skin cancer. The first phase in this work is to prepare images data, this include images segmentation to find useful parts that are easier for analysis and to detect region of interest in digital images, reduce the amount of noise and image illumination, and to easily detect sharp edges (boundaries) of objects. Then, the proposed approach built a convolutional neural network model which consists of three convolution layers, three max pooling layers, and four fully connected layers. Testing the model produced promising results with accuracy of 0.74. The result encourages and motivates for future improvement and research on online diagnosing of melanoma in early stages. Therefore, a web application was built to utilize the model and provide online diagnosis of melanoma.**

***Keywords*—Convolutional neural network CNN; melanoma; skin cancer; image preprocessing**

I. Introduction

Skin cancers (lesion cancer) are the most common of all cancers, where abnormal growth of skin cells with the ability to spread to neighboring cells or other parts in the body. In most cases, skin cancers are caused due to exposure to ultraviolet radiation from the sunlight or from some cosmetic devices such as tanning beds. Skin Cancers can be categorized into three main types: Melanoma, Squamous Cell skin Cancer (SCC), and Basal Cell skin Cancer (BCC). Melanoma is the most damaging and common type of skin cancer and can appear on eyes or mouth, where SCC and BCC are less common and do not spread to other areas and unlikely to cause death, Fig. 1 shows samples of skin cancer images [1].

The main symptoms of melanoma cancer is the appearance of large brown spot, spread by other patches smaller and darker color, changes in color and size of moles in the body, or the descent of blood from them, as well as, the appearance of dark small and irregular edges lesion, usually on the hands and feet [2]. The American cancer society expect about hundred thousand new melanomas cases in United States in 2019, 60% are men and 40% are women, and about thousands of skin cancer patients are expected to die due to melanoma in US during 2019 [3], in addition, the American cancer society found that the percentage of diagnosed skin cancers increased 54% for the period between 2008 to 2019, and likely to diagnose 104,350 new cases in 2019 in U.S, and the estimated death is 11,650 where 8,030 are male and 3,620 are female. Therefore, there is a tremendous need for computer application to provide rapid and initial diagnoses advice for potential skin cancer [4].

Diagnosing skin cancers in early stages could increase the survival rate and save medical cost and treatment for potential patients. Computer-Aided application for diagnosing skin cancers can contribute to timely detection of skin cancers before it is too late, and encourage potential patients to seek further pathology test and physicians advices.

The purpose of this paper is to explore the efficiency of using Deep Learning Neural Network in medical images, practically, skin cancers images. The aim is to develop a computer application that receive captured image from end-user, then response to end-user with a set of recommendations such as the percentages of skin cancer in the captured image and a set of procedures to follow. Early diagnosis and detection of skin cancer can prevent patients from consequences such as surgical procedure to remove skin cancer as shown in Fig. 2. The rest of the paper is organized as the following: Section 2 express the literature review about the subject and previous attempts to utilize medical images and neural networks for the purpose of diagnosing melanoma, Section 3 describe the uses of neural network for medical images analysis and prediction, Section 4 is designated to present the methodology and material used in the research, Section 5 is to discuss the main results and finding obtained, and Section 6 is to conclude the main theme and results in this research.

(A) (B) (C)

Fig. 1. Sample Skin Cancer Images, (A) Basal Cell Skin Cancer, (B) Squamous Cell Skin Cancer, and (C) Melanoma.

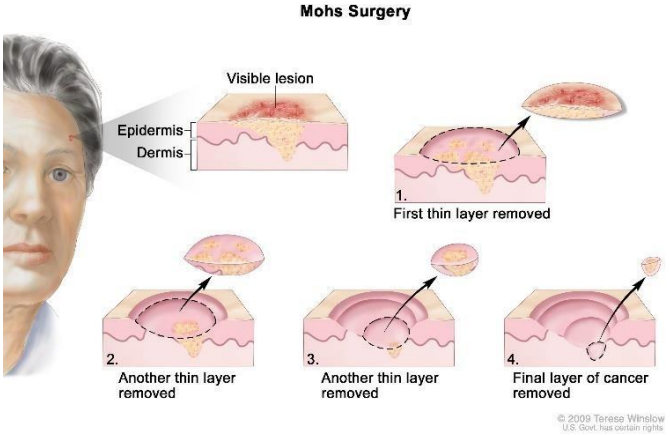

Fig. 2. A Surgical Procedure Steps to Remove Skin Cancer [2].

II. Neural Network for Medical Analysis

Computer vision is a way to understand or simulate human vision of things (objects, events, motion, etc.) and attempt to make computer to do the same, by simulating brain images and videos processing that come from the retina. Computer vision can be defined as a branch of Artificial Intelligence (AI) that focus on using geometry to transform digital image or sequence of images (video) into high dimensional data, and then extract features, such as texture, points, lines, edges, shapes, motions, and ridges. A common application of computer vision is medical image processing, which aims to obtain significant information from images to automate patient's diagnosis. An example of this automation is computer-aided detection of breast cancer and skin cancer [7].

Artificial Neural Network (ANN) is the very fundamental of deep learning. ANN originally presented by the neuro physiologist Warren McCulloch and the mathematician Walter Pittsin 1943. They proposed the first neural network architecture (computational model) inspired from human biological neuron (Fig. 3) of how biological neurons are connected together in animals' brains to transmit data and accomplish complex computations tasks. In 1960, further ANN architectures contributed to believe in machine intelligent, then ANN entered forgetting era till 1980 when gained interest again, but 1990 shown newly invented alternative machine learning techniques much powerful than ANN such as SVM (Support Vector Machines). Recently, ANN gained another life chance due to the huge amount of quality data and significant increase in computers storage and power which assisted ANN to produce better results. Nowadays, ANN and its related techniques are considered as a powerful machine learning tool to tackle large and highly complex tasks, for example, Google uses deep learning to classify tremendous number of images, Apple's Siri speech recognition tool, and YouTube for suggesting best related videos for the big number of users every day [5], [6].

Computer vision and image classification problem were among the main factors of development of deep learning, because AI researchers aimed to learn features from raw of images which require higher computations and memory resources in compare to text and numerical learning models. In particular, the network called AlexNet has been used and modified to solve computer vision and image classification problems which draw the map for the Convolutional Neural Network (CNN) [8].

The increased popularity in Convolutional Neural Networks in medical analysis and computer vision is due to its outstanding performance in analyzing and classifying images. Consequently, CNN became one of the most popular models in deep learning and computer vision. The key idea behind convolutional neural networks is to build partially connected layers. For example, an image with shape 100 × 100 which form 10,000 pixels as input to the network and suppose the first layer consist of only 1000 neurons then the number of connections between input layer and first hidden layer will be about 10 million connections, which require huge computations and memory. However, CNN can resolve this issue using partially connected layers. In CNNs, there are receptive fields to connect the input layer to a feature map. Receptive fields can be defined as overlapping windows that travel over the pixels of an input image to create a feature map. The shifting length in input image window and the size of window itself is determined during model design and implementation. The process of creating the feature map is also called convolution. An example of such a convolutional layer, the layer that connects the input pixels to each unit in the feature map, is shown in Fig. 4 [9], [10].

The convolutional neural network is typically consisting of three layers, convolution layer, pooling layer, and fully connected layer. In addition, CNN may contain optional layers such as dropout layer, however, convolution, pooling, and fully connected layers are the most popular architecture for CNN.

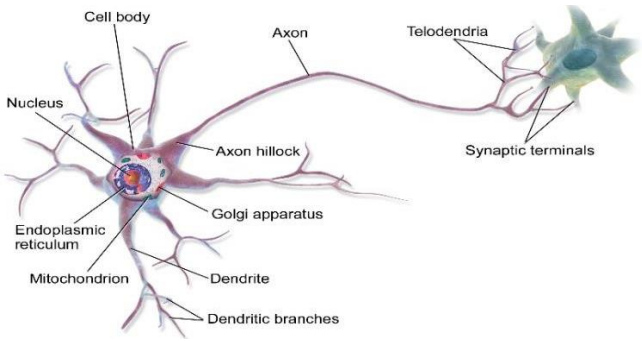

Fig. 3. Biological Neuron.

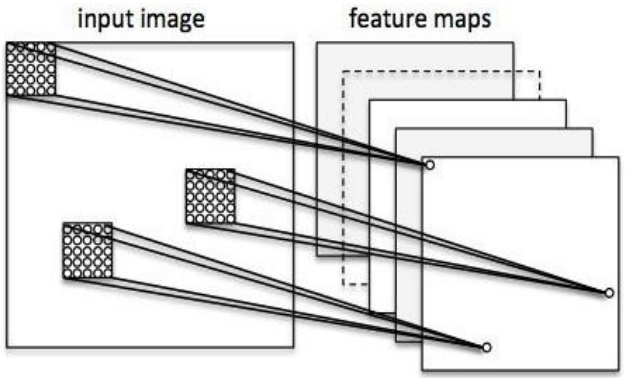

Fig. 4. An Example of a Convolutional Layer, the Layer that Connects the Input Pixels to Each unit in the Feature Map.

A. Convolution Layer

The convolution layer is the central structure for CNN and performs the most computational load. This layer performs a dot product between two matrices, the first matrix is the set filters also known as kernels and usually smaller in size than the image itself, for example, kernels for detecting vertical or horizontal edges. The second matrix is window matrix of the receptive field which is typically a portion of image with predefined size and sliding. Most of the images are composed of three channels (RGB), therefore, the kernel and receptive field will be also extending to three channels too. Initially, the kernel travel across input image with to produce smaller image that map input image with kernel, sample output of convolutional layer is shown in Fig. 5 [11].

B. Pooling Layer

The main purpose of pooling layer is to reduces the size of output which produced from previous layer (convolution layer), reducing the size of features will reduce the computation time and makes features robust against noise and outliers. There are several ways to do pooling such as max pooling and average pooling, however, the most popular is max pooling which calculate the maximum output from the neighborhood as shown in Fig. 6 [12]. Sample fully connected layer is shown in Fig.7.

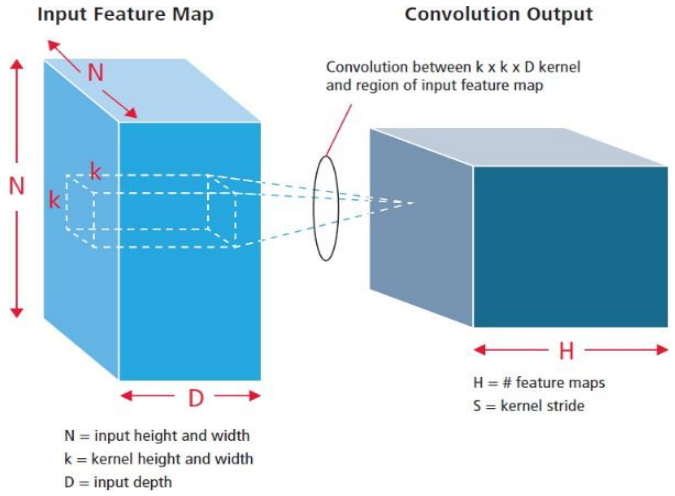

Fig. 5. Representation of Convolutional Process [11].

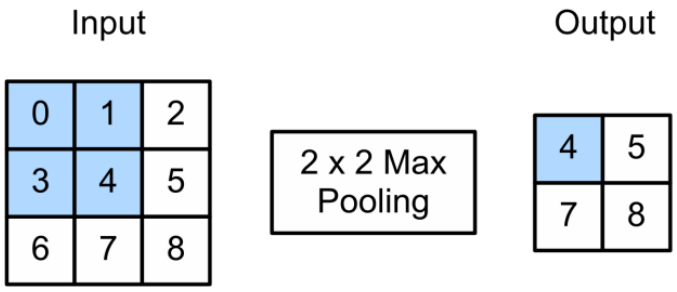

Fig. 6. Maximum Pooling with a Pooling Window Shape of 2×2 [12].

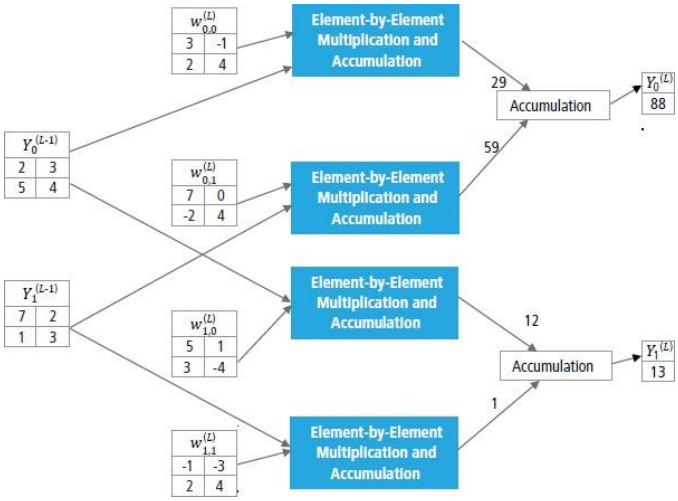

Fig. 7. Sample Fully Connected Layer [12].

III. Literature Review

The literature shows several attempts to diagnose skin cancer cases using deep learning techniques, such as CNN. Esfahani et al. [13] proposed CNN architecture for diagnosing melanoma lesions, clinical images were preprocessed in order to reduce image illumination, then images fed to convolutional neural network models. The CNN model was successful to distinguish between malignant and benign images. Experimental results show that the proposed method was capable to diagnose melanoma lesions cases.

Giotis et al. [14] presented an expert system call MED-NODE to aid doctors in melanoma detection. The proposed system used extracted lesion regions in the image, then computes indicators such as the color and texture, along with visual attributes provided by experts. The proposed system performed comparably to state-of-the-art methods.

Mahbod et al. [15] shown that convolutional neural networks is superior over traditional methods. They proposed a a hybrid fully automatic computerized method for skin lesion classification, they used three pre-trained deep models (AlexNet, VGG16, ResNet-18) to extract features. The extracted features then are used to train SVM (support vector machine) classifiers and evaluated on the 150 validation images from the ISIC 2017 dataset, the proposed method is shown to achieve very good classification performance.

Jaisakthi, Chandrabose, and Mirunalini [16] proposed a method for skin lesion segmentation in images and to classify skin cancer types from images. The proposed method consists of preprocessing and segmentation using semi-supervised learning algorithm. The purpose of the first phase is noise removal using filtering technique, the second phase skin lesions are segmented based on clustering technique. The training images were downloaded from the ISIC 2017 challenge website, the experimental results shown low accuracy but will draw a map for future improvement.

IV. Method and Material

A. Dataset

Dataset used in this manuscript was downloaded from the ISIC 2017: Skin Lesion Analysis Towards Melanoma Detection challenge website. This challenge provides a set of 2,000 publicly available dermoscopic images to participants. The data set also includes validation set with 150 images and test set with 600 images, Table I shows dataset statistics and Fig. 8 shows sample images from the dataset.

B. Methodology

Preprocessing data is among the most important phases in data science project, the idea is use a systemically approach to prepare data before feeding data into machine learning models. Segmentation is a popular preprocessing approach when the analysis and to detect objects and objects boundaries in digital images. In this work, Dataset images are RGB format (Red, Green, Blue) and since RGB images are more linked with the amount of light and illumination; it make it difficult to extract image features and boundaries, therefore, all images have been converted into HSV color space (Hue, Saturation, Value) which are more useful and relevant for objects detections in digital images. The second phase in dataset preprocessing is to apply Bilateral filter to all images, to keep sharp edges in the image because Bilateral filter substitutes the intensity of each pixel with a weighted average of intensity values from neighboring pixels [16]. The third step is to convert images into grayscale images to reduce the complexity and dimension of images then automatically detect edges of the objects in an image using Canny edge detection method. Final step of preprocessing is to create a mask for each image and then apply Bitwise method to extract the desired object in image; Fig. 9 shows an example of prepressing one image.

Since the dataset is not balanced (1626 benign and 374 malignant), augmentation technique used to generate and boost training images. Therefore, we used image zoom and image shift methods to produce 3000 images for each class label, Fig. 10 shows sample augmentation for one of the images.

After preparing the dataset, the next phase is to feed training dataset into Convolution Neural Network Model. Fig. 11 shows the architecture of CNN, which consist of three convolution layers, three max pooling layers, and four fully connected layers.

TABLE. I. Dataset Description

Cancer Diagnosis	Count		Total
Benign	Nevus	Seborrheic	1626
	1372	254	
Malignant	374		374

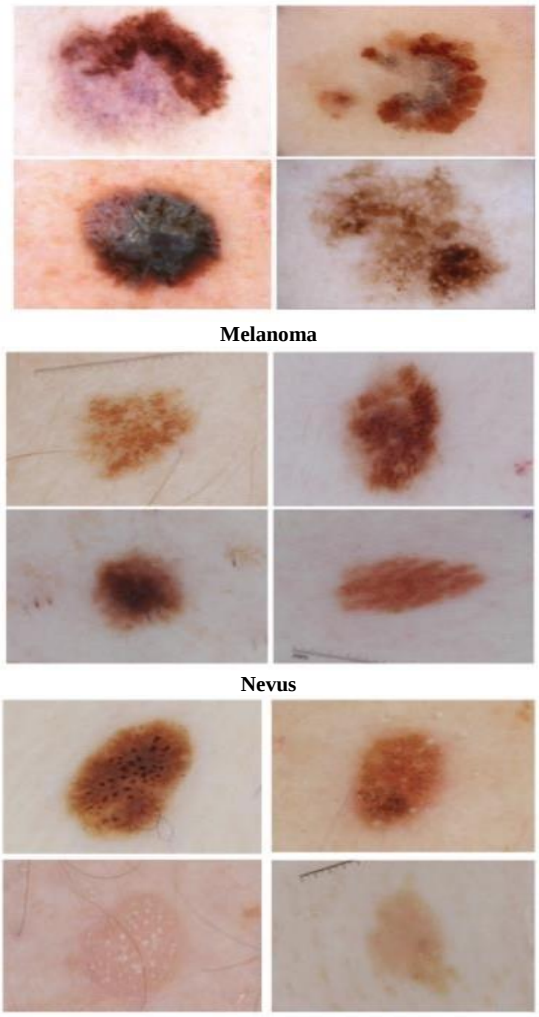

Fig. 8. Sample Images from the Dataset.

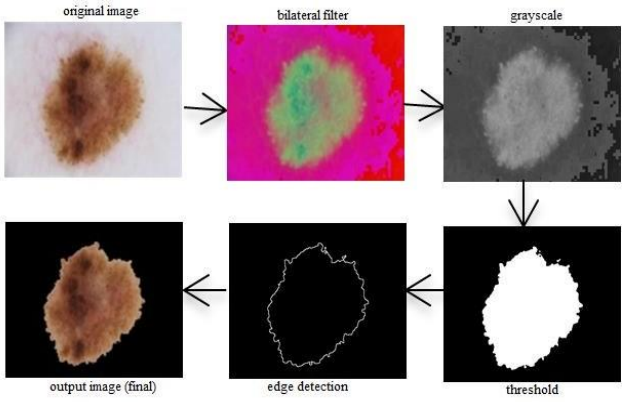

Fig. 9. Dataset Preprocessing Steps.

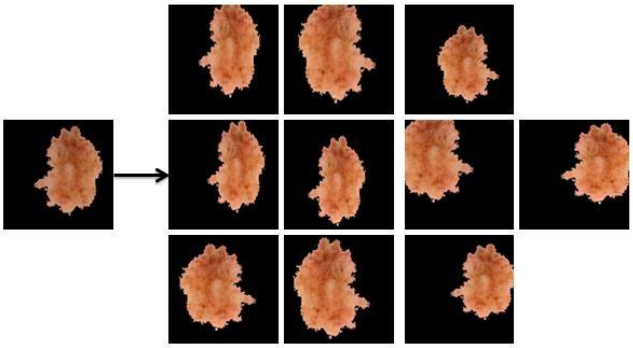

Fig. 10. Image Augmentations for Boosting Training Dataset.

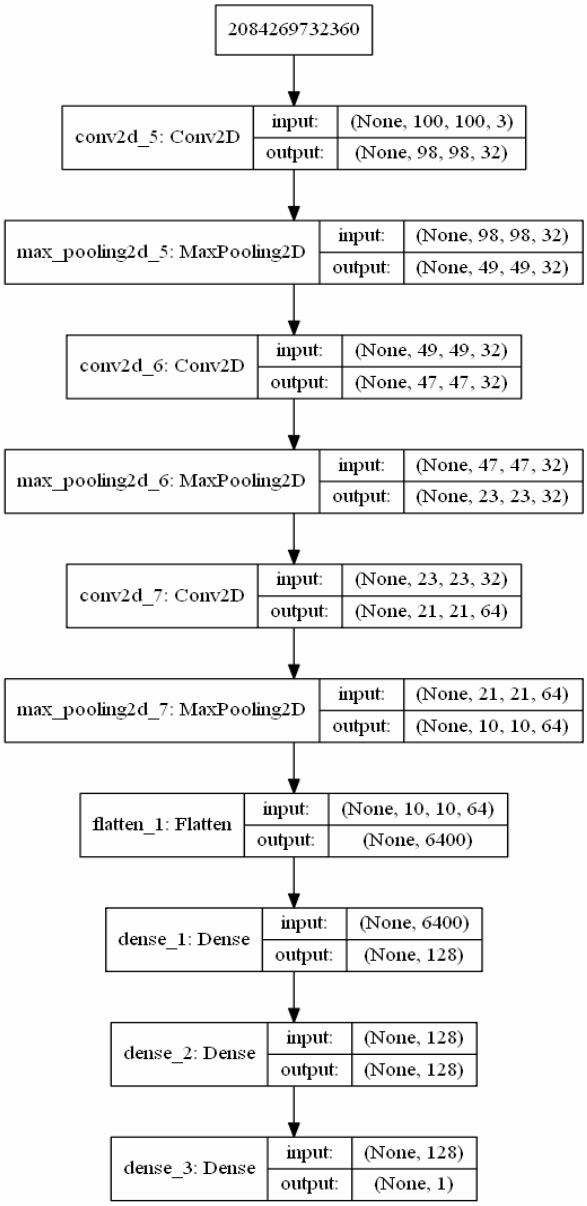

Fig. 11. CNN Architecture Model for Diagnosing Melanoma.

V. Results and Discussion

The available dataset was applied to the proposed model for diagnosing skin cancers using convolutional neural network. Number of epochs was set to 25. Accuracy on first epoch was and increased slightly in almost every following epoch to reach maximum accuracy of 0.74 on epoch number 25 which shows a satisfactory accuracy for diagnosing melanoma as shown in Fig. 12. In summary, our method shown pleasing but not superlative results, the importance of this work is to show the ability of early detection of melanoma using deep learning techniques such as convolutional neural network, which could draw the map for future research and investigation.

The trained CNN model has been saved in *h5* file format to store the weights and model configuration in a single file, which can be used in webserver to receive new unseen cases and produce an output or diagnosis online for users.

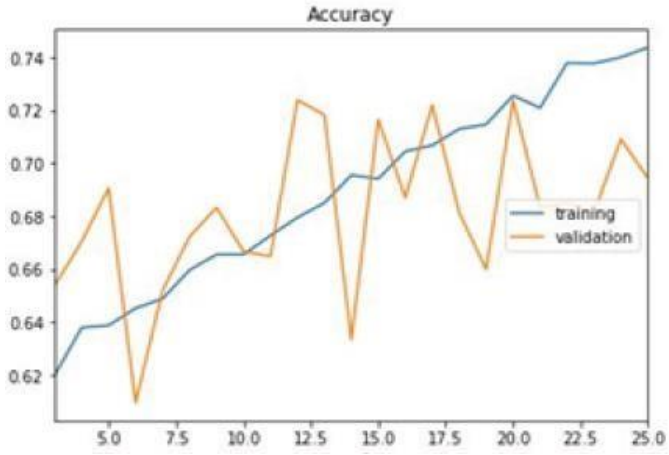

Fig. 12. Model Accuracy over 25 Epochs.

VI. Conclusion

In this paper, a computational method based on deep learning (Convolutional Neural Network) was implemented, which utilized 2000 images provided by ISIC (International Skin Imaging Collaboration). The proposed method includes images preprocessing for extracting the region of interest in the image itself, and then augmenting some images to produce a bigger dataset which contains 3000 images for each class. The resulting dataset have been applied into CNN model to train the model, which comprise several layers such as convolution layers, pooling layers, and fully connected layers. Testing the model produced promising results with accuracy of 0.74. The result encourages and motivate for future improvement and research for online diagnosing of melanoma in early stages before it is too late. Future work of current research is to investigate and restructure the CNN architecture to increase accuracy, obtain more images data for training, apply new augmentation algorithms to train the model using more data, and the ultimate future plan is to make this model accessible and useable using smart phones applications.

ACKNOWLEDGMENT

I would like appreciate ISIC (International Skin Imaging Collaboration) for providing freely and publicly dataset for skin cancer, Yarmouk University, and students Mahmoud Al-Hammouri, Mohammad Alomar, and Khalil A-lsaleh for their efforts, discipline, and cooperation during this work.

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A Review of Embedding Hexagonal Cells in the Circular and Hexagonal Region of Interest

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***Abstract*—Hexagonal cells are applied in various fields of research. They exhibit many advantages, and one of the most important is their possibility to be closely packed and to form a hexagonal grid that fully covers the Region of Interest (ROI) without overlaps or gaps. ROI can be of various geometrical shapes, but this paper deals with the circular or hexagonal ROI approximations. The main purpose of our research is to provide a short review on the literature concerning the hexagonal grid, summarizing the existing state-of-the-art approaches on embedding hexagonal cells in the targeted ROI shapes and offering application-specific advantages. We report on formulas and algebraic expressions given in the existing researches that are used for calculating the number of embedded inner hexagonal cells or their vertices and/or edges. We contribute by integrating all researches in one place, finding a connection between previously unrelated applications concerning the use of embedded hexagonal grid and extracting commonality between previous researches on whether it provides the formulas on calculating the inner hexagon cells. In case only the number of edges or vertices is provided for the targeted application, we derive formulas for calculating the number of inner hexagons. Therefore, our survey results with the overview on solving the problem of embedding hexagonal cells in the desired circular or hexagonal ROI. The contribution of the review is the following: first it provides the existing and the derived formulas for calculating the embedded hexagons and second, it provides a theoretical background that is necessary to encourage further research. Namely, our main motivation, that is the geometrical design of the one of the world's largest CERN particle detectors, Compact Muon Solenoid (CMS) is analyzed as a source for the future research directions.**

Keywords*—Detector design; hexagon tessellation; region of Interest; regular grid

I. Introduction

Hexagonal grids are used in many different scientific fields, due to its advantages compared to other approaches. According to some researches, it has been found that using a hexagonal instead of a traditional square grid provides better results in digital image and signal processing [1-7]. In biological application, the advantage of using hexagons is present in observations, simulations and experiments, with a special benefit provided in biological modelling [8].

Many authors prompt the hexagonal grid usage, especially in cartography, because of the possibility to derive smaller resolutions by applying decomposition of the larger cells into smaller ones [9, 10]. The use of a hexagonal cells is inevitable, since hexagonal grid offers many general advantages compared to other regular grids that use square or rectangular arrays. First, resource savings can be obtained. For example, when applied in engineering, hexagonal sensor shape enables reduced material waste when it is produced from a circular silicon wafer [11, 12]. Also, the data processing is faster with the hexagonal structure and the needed memory usage for data storage is decreased (13.4% compared to rectangular grid [13]). Also, the processing resources are reduced [14, 15].

Besides, important advantage of a hexagonal grid is that the nearest cells are equidistant from a single rounded cell, such that the nearest neighbor finder algorithm is less ambiguous than with using squares or rectangles [8, 15, 16]. Another advantage of the hexagonal grid is the possibility to fully cover the Region of Interest (ROI) without void or gaps. The increased area usage is shown with hexagons compared to other polygon shapes [17, 18].

There are many applications of the general hexagon usage, but not so many address a specific problem of embedding the hexagonal cells in a selected ROI. Also, according to our knowledge, no paper based on the general survey on the former question is found in the existing literature. Therefore, the aim of this paper is to provide a short review on the current topic. We concentrate on a specific case where ROI is approximated with a circular or a hexagonal shape. We classify the papers from the literature in two main classes depending on the ROI used. Next, subclasses are derived based on the practical application or the certain field of research. Further and final categorization is done based on the mathematical formulas that are provided in the paper, whether for the calculation of the total number of hexagonal cells embedded in the ROI, or the number of the corresponding inner hexagon vertices and edges.

In case that the number of inner hexagonal cells is not provided in the referent papers, we derive formulas for the total number of hexagons embedded in the ROI. The goal of this overview is to provide the existing mechanisms of hexagon cells calculation in the hexagonal and circular ROI, with the aim to develop a framework for sensor modelling in the sensing region. Our targeted application is the Compact Muon Solenoid (CMS) detector geometry, which should be designed and analyzed. The basic intention is to calculate the total number of hexagonal sensors needed to cover a sensing layer in the hexagonal modular and circular detector region to enable the evaluation of the sensor production cost in the future work.

The paper is organized as follows. In Section II, methodology for the survey is given with the posed research questions and context. Also, the search and selection result of the literature papers is summarized in tables based on the pre-defined categorization strategy. Section III deals with the theoretical background on the hexagonal grid and the ROI definition. A short review on the hexagonal cells embedded in the circular and hexagonal ROI is given in Section IV. The research findings are summarized in Section V. Definition of the new CMS detector geometry model is presented in Section VI and the future research directions are derived. Section VII concludes the paper followed by references used.

II. Methodology

A. Research Questions

With this survey, we intend to answer the following research questions:

- RQ1: Which applications can be found in the literature that deal with embedding the hexagonal cells in circular or hexagonal ROI?
- RQ2: Are there algebraic expressions provided in the literature that calculate the number of the ROI-embedded hexagonal cells and/or the number of their vertices and edges?
- RQ3: How to derive formulas which provide calculation of the embedded inner hexagonal cells in the ROI?

B. Research Context

The search strategy was applied to find the relevant papers published in conferences and journals. Hence, a manual and automatic search was done by using the IEEE Xplore and Google Scholar. A search concatenated string used as a basic criterion for the paper collection was: “hexagon”, “region of interest”, “packing” and “circle”. Only studies published in English were included in the review and rejected otherwise.

When the initial set of papers is obtained, we excluded the duplicates. Each papers’ title, abstract and keywords were analyzed to evaluate its relevance. Papers were kept if they addressed the RQs and excluded otherwise. The total collection of papers divided into conferences (5 papers) and journals (37 papers) is given in Table I.

C. Paper Search and Selection Result

Papers were divided in two basic classes depending on whether a circular or a hexagonal ROI is used. Next, the papers from each class are separated based on the specific application. The search and selection results are given in Table II for circular and Table III for hexagonal ROI shape.

TABLE I. Papers Divided by Type

Paper type	**Extracted papers**	
	References	***Total #papers***
Conferences	[1], [4], [7], [16], [32]	5
Journals	[2], [3], [5], [6], [8-15], [17-31], [33-42]	37
Total #papers	42	

TABLE II. Papers using Circular ROI (class 1)

Application	**Provided Mathematical Formulas**		
	#hexagonal cells	***#vertices***	***#edges***
Sensor manufacturing	[12]	[]	[]
WSN	[21]	[]	[]
Total #papers	2		

TABLE III. Papers using Circular ROI (Class 2)

Application	**Provided Mathematical Formulas**		
	#hexagonal cells	***#vertices***	***#edges***
Interconnection networks	[22], [24]	[22-24]	[22], [23]
Discrete applied mathematics	[25]	[25-28]	[25], [26]
Silicate Networks	[]	[29], [30]	[29], [30]
Wireless Sensor Networks (WSN)	[32], [34-36]	[32]	[]
Hierarchical grids	[8], [9], [37], [40]	[]	[]
Total #papers	17		

We further categorized the papers from each application in sub-classes depending on whether authors provide formulas on how to calculate the total number of embedded hexagonal cells, their vertices or edges.

III. Theoretical Background

A. Hexagonal Grid

Hexagonal grid is formed by a regular tessellation of hexagonal cells used to cover the ROI without overlaps or gaps ([19]).

The hexagonal coordinate system can be defined by using various definitions [20], and we present the basic one with using two coordinate axes at $\pi/3$ angle so that a discrete indexation of each hexagonal cell becomes possible, as shown in Fig. 1.

B. ROI Definition

ROI can be approximated by any geometrical shape, but in this paper, we are interested in applications where ROI is a circle or a hexagon.

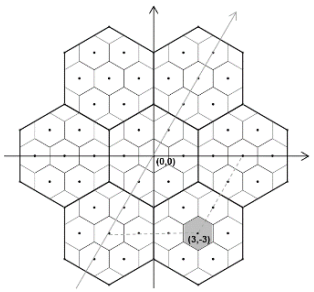


Fig. 1. An Array of Cells in the Hexagonal Grid.

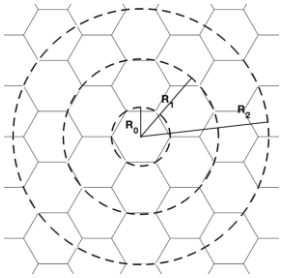


Fig. 2. Hexagonal Grid Embedded in the Centered Circle.

Based on the conducted survey, there are more papers dealing with hexagonal ROI application, even though ROI approximation with a circle is more appropriate because of the simplicity of the mathematical calculations. The process of embedding hexagonal grid into circle can be equaled by the intent to encircle the hexagonal cells in the grid, where the circle center is shared with the central hexagonal cell in the coordinate system origin (0, 0). However, there are many possible ways of grid encircling, as given on Fig. 2.

Also, ROI can be approximated by some other geometrical shape such as a polygon rather than circle, and we concentrate on the applications where ROI is a hexagon. The selection of these two ROI shapes is application-driven, as we target a potential geometry model for a specific application such as CMS detector sensing layer design. Our goal is to explore the state-of-the-art mathematical formulas provided in the literature or derived from the findings. Hence, in this paper, a short comprehensive review was conducted to describe, compare, and analyze the existing approaches or a related work on embedding hexagons into hexagonal or circular ROI. These are discussed thoroughly in the next section.

IV. Review on Hexagons Embedded in the ROI

A. ROI Approximated by a Circle

In sensor manufacturing, circular ROI is a silicon wafer from which hexagonal sensors are fabricated. In WSN, network sensing field or covered range can be depicted by a circle of a given radius, which is a ROI in the current context.

Embedding hexagonal grid in the circular geometrical shape is interesting to study because of the many ways it can be encircled. The number of hexagonal cells embedded in the ROI must be calculated and adjusted accordingly, so that they are entirely contained inside a circle, or some compromises must be agreed on the ROI border.

1) Sensor manufacturing: Bothra [11] considered forming semiconductor dies from smaller hexagonal sensor cells embedded on the circular wafer. Author used a hexagonal grid embedded into a circular ROI, to show that larger area can be used on wafer with using hexagons compared to other geometrical shapes. The waste of the silicone material thrown away is reduced as well as the total production cost.

There is an attempt from Davis and Sinha [12] on forming the central hexagonal polygon dies, and several smaller outer polygons arranged around the central die (Fig. 3). Authors show that hexagonal grid enables more polygon sensors to be produced compared to a square grid when the wafer radius is constant. Authors provide examples on calculating the total number of embedded sensor cells in Table IV but do not provide formulas for their calculation.

We reconstruct the total inner hexagonal or squared cells number according to Table IV as:

$$N_{hexagons}(k) = 3k^2 + 3k + 1$$

$$N_{squares}(k) = 4k^2 \quad (1)$$

In both cases, parameter k is number of "rings", or maximum number of dies from the central die to the border (if there is central die in the tessellation like in hexagonal case, counting starts from 0, otherwise it starts from 1). If the full tessellation does not place all the full dies on the wafer, some dies in the most outer ring are cut out by the wafer radius. Those dies are taken out from the total number of embedded sensor cells given by the formulas.

2) WSN: Unlike other grid-based regular deployment patterns in WSN, it is shown that hexagonal grid provides better coverage efficiency since it can cover the sensing area better than triangles and squares [17]. Kim et al [21] use a hexagonal grid with an ideal cell size to deploy the underwater WSN. Authors show that for a circular ROI, one can calculate number of hexagon rings needed to fully cover the disk of a given radius (Fig. 4).

TABLE IV. Calculating #Sensor Cells [12]

Side length a [mm]	Area per die [mm^2]	# square dies	# equivalent hexagon dies
10	100	594	649
20	400	148	151
30	900	52	61

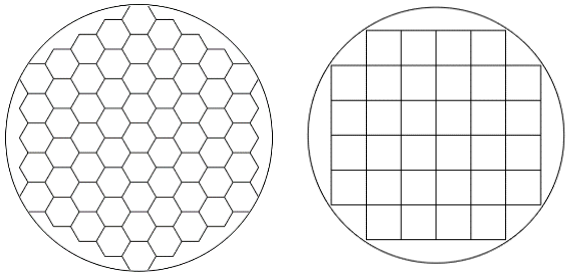


Fig. 3. Calculating #Sensor Cells (Adjusted from [12]).

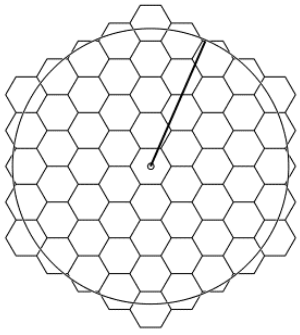


Fig. 4. Hexagon Ring Calculation in WSN (Adjusted from [21]).

The applied formula to calculate the number of embedded hexagonal cells is the following [21]:

$$N_{hexagons} = \begin{cases} \frac{(3q+1)l}{2} = R & if\ q\ is\ odd \\ \frac{l\sqrt{(3q+1)^2+3}}{2} = R & if\ q\ is\ even \end{cases} \quad (2)$$

Therefore, the total number of hexagon rings is denoted by q, and the small hexagon side length is given by l. To calculate q needed to fully cover the ROI of radius R, relation (2) must be satisfied. The number of hexagons in each hexagon ring k is given by the following formula [21]:

$$N_{hexagons} = 6k,\ k = 1, 2 \ldots \quad (3)$$

Equation (3) enables one to calculate the number of hexagon rings. For example, having ROI of radius $R = 100$ and given the cell size $l = 9.991$, the number of hexagon rings $q = 7$. Thus, we can calculate the number of hexagonal cells need to be fit inside a pre-defined circular ROI.

B. ROI Approximated by a Hexagon

1) Interconnection networks: Interconnection network consists of nodes processing the data in parallel. It is often modelled by the honeycomb network (HN) or the hexagonal network (HX) naturally contained into a hexagonal ROI. The various topology characteristics are studied depending on the application. For example, authors derive formulas to calculate the number of smaller hexagons inside the larger one, as well as the number of inner small hexagon edges or vertices.

The basis is the work of Stojmenovic [22], presenting the problem of building a hexagonal grid or how to construct a honeycomb network. Example of HN(t), where the radius t is the number of hexagon rings between the network center and the ROI border is shown on Fig. 5. We can see how a honeycomb hexagonal mesh network is contained or embedded inside a regular hexagonal ROI.

The total number of vertices of HN(t), is calculated as $6t^2$ and the total number of edges is $9t^2 - 3t$. The diameter (the largest distance between two nodes) is $d = 4t - 1$. These parameters are important for evaluating the network performance and cost influenced by the total number of network parallel nodes and links.

We derive the size of the HN(t) in terms of total number of hexagons:

$$N_{hexagons} = 3t^2 - 3t + 1 \quad (4)$$

Chen et al. [23] proposed how to count the number of nodes n as a function of a given distance t from the center node to the network vertex in a hexagonal network HX(t) presented on Fig. 6. The total number of nodes of HX(t) is $n = 3t^2 - 3t + 1$, the total number of edges is defined as $e = 9t^2 - 15t + 6$. The diameter (number of links on the hexagonal ROI circumscribed circle) is $d = 2t - 2$.

Authors did not provide formulas for calculating the total number of embedded hexagonal cells. Therefore, we derive the formula based on the total edges/vertices count:

$$N_{hexagons}(t) = 3t^2 - 9t + 7 \quad (5a)$$

All inner nodes in the network can represent the center of one hexagonal cell, so if overlapping is allowed, the number of hexagons is provided by (5a). Number of hexagons in non-overlapping case can be calculated with the following formula, where $t = 2k + l,\ k \in N_0,\ l \in \{0,1\}$:

$$N_{hexagons} = \begin{cases} 3k^2 - 3k + 1 & if\ l = 0 \\ 3k^2 - k & if\ l = 1 \end{cases} \quad (5b)$$

All parameters n, e, d and the number of hexagons is considered as a function of t, representing the size of the network [24]. Honeycomb network HC(n) is obtained from HC(n−1) by adding a ring of hexagons around the boundary of HC(n−1) [25]. It means that the number of nodes in each hexagon ring up to t equals (3), and the total number is again a cumulative sum (4).

2) Discrete applied mathematics: We can consider a problem of defining hexagonally shaped honeycomb and hexagonal networks to be the same as embedding hexagonal cells in a hexagonal ROI. This is a well-known problem in applied discrete mathematics, where a connection between hexagonal and honeycomb networks is studied. By the definition, every honeycomb network HN(t-1) is contained inside some hexagon network HX(t) [25, 26]. Considering the example on Fig. 7, it is clearly indicated that, to embed a hexagonal grid in the hexagonal ROI, one needs to find its dual HX. Also, in the opposite procedure, the dual HN embedded in the HX of the ROI can be examined. The number of hexagons is again (4).

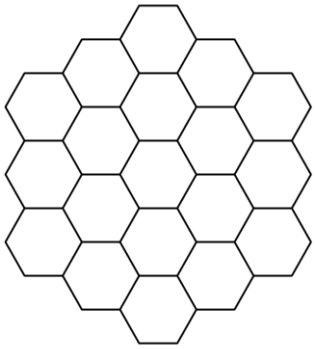


Fig. 5. Honeycomb Network HN (3) (Adjusted from [22]).

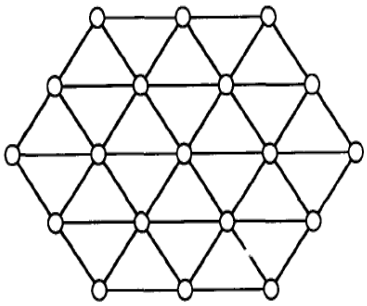


Fig. 6. Hexagonal Network HX (3) [23].

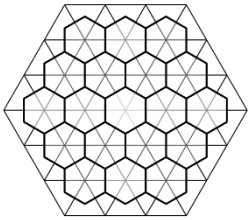


Fig. 7. HN (3) is Contained Inside HX (4) (Adjusted from [26]).

A mathematical problem of embedding a hexagonal grid into a bounding hexagon is presented in the literature as a degree diameter problem considering a graph as being embedded in host graph such as honeycomb network. This problem involves finding the largest sub graph in terms of the number of vertices subject to constraints on the degree and the diameter [27]. Diameter D is total number of edges on the circumscribed circle diameter of the hexagon by which the graph is encircled (Fig. 8).

In the former context, a host graph is encircled by a hexagonal ROI with the size given by D. Formulas are developed to find the total number of inner vertices, divided into classes based on the odd and even diameter size [27]:

$$|V(H_D^2)| = \begin{cases} 6k^2+3k+1, & when\ r=0 \\ 6k^2+6k+2, & when\ r=1 \\ 6k^2+9k+4 & when\ r=2 \\ 6k^2+12k+6 & when\ r=3 \end{cases} \quad (6)$$

In the above formulas, H is the honeycomb grid, where H_D^2 denotes a largest subgraph of H of diameter $D = 4k + r, k, r \in N, r \in \{0,1,2,3\}$. Depending on the ROI size, for it to be a hexagonal shape, the diameter must be even. Also, for $D = 4k$, ROI is a regular hexagon and for $D = 4k + 2$, ROI is an irregular hexagon. Fig. 8 gives an example for both. Authors in [27] do not provide the total number of hexagons embedded inside the ROI. We derive the former with the following formulas:

$$N_{hexagons} = \begin{cases} 3k^2, & when\ r=0 \\ k(3k+3), & when\ r=2 \end{cases} \quad (7)$$

There is a similar attempt to solve the degree diameter problem while counting the total number of vertices of the sub-graph based on the triangular grid which is the basis for hexagonal networks [28]. It is expressed as a function of diameter, defining two classes of architectures, depending on weather the diameter is even or odd:

$$N_T(D) = \begin{cases} \frac{3}{4}D^2+\frac{3}{2}D+\frac{3}{4} & for\ odd\ D \\ \frac{3}{4}D^2+\frac{3}{2}D+1 & for\ even\ D \end{cases} \quad (8)$$

Again, even diameter size architecture explicitly touches upon an issue of embedding hexagonal grid into a hexagon. Also, even diameter size is implying a regular hexagonal ROI, while the odd diameter size is used when ROI is the irregular hexagon (Fig. 9). Equation (8) enables one to calculate the total number of inner cells' vertices [28]. We derive formulas to calculate the total number of inner hexagons:

$$N_{hexagons} = \begin{cases} \frac{3}{4}(D-2)^2+\frac{3}{2}(D-2)+\frac{3}{4} & for\ odd\ D \\ \frac{3}{4}(D-2)^2+\frac{3}{2}(D-2)+1 & for\ even\ D \end{cases} \quad (9a)$$

Formula (9a) allows overlapping hexagons. If overlapping is not allowed, and $D = 4k + r, k, r \in N$ the total number of hexagons is given by:

$$N_{hexagons} = \begin{cases} 3k^2-k & when\ r=0 \\ 3k^2+k & when\ r=1 \\ 3k^2+3k+1 & when\ r=2 \\ 3k^2+3k+1 & when\ r=3 \end{cases} \quad (9b)$$

3) Silicate networks: There are researches in which embedding of the honeycomb and hexagonal networks into silicates are studied. Naturally, a hexagonal ROI shape is used. For example, Manuel et al. [29] show a silicate network can be constructed from hexagons. Authors calculate the total number of hexagon nodes and edges in the network. HX (n) node labeling before a silicate network construction is given on Fig. 10.

One can see on the figure that hexagons are clearly emphasized inside a hexagonal ROI. However, authors do not provide their total number. We derive the former with the following expression:

$$N_{hexagons} = \frac{3}{4}t^2 - \frac{3}{2}t + 1 \quad (10)$$

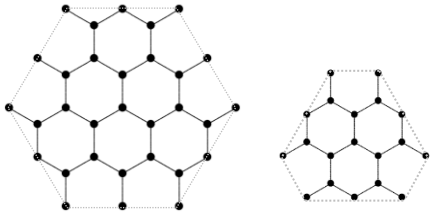


Fig. 8. Honeycomb Grid with D = 8 and D=6 (Adjusted from [27]). We Added the Light Gray Border to Visualize the ROI Shape.

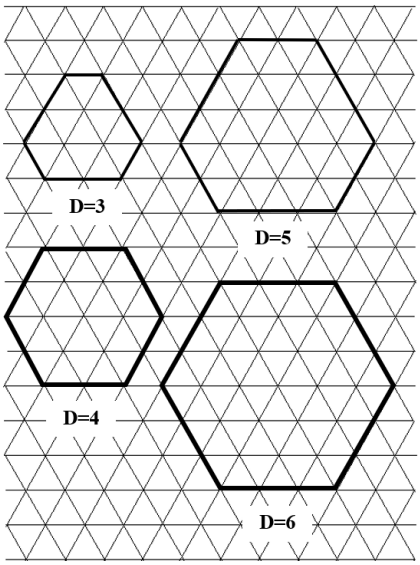


Fig. 9. The Graphs for D = 3, 4, 5, 6 (Adjusted from [28]).

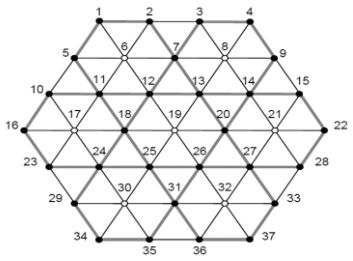


Fig. 10. HX Node Labeling [29]. White Nodes Represent Centers and Black Nodes are Vertices of the Inner Hexagonal Cells.

Parameter t in the upper formula (10) is a total number of vertices from the central node to the network vertex.

In the former context, there are some other papers addressing the construction of the new, not only hexagon-like structures, derived from hexagonal and honeycomb networks with using graph operations. Basic properties of the defined topologies are investigated, such as the total number of hexagon vertices and edges [30].

4) WSN: To enable an efficient area coverage in WSN, it is not enough to position sensors only at vertices of the hexagon cells in a hexagonal grid. When covering a large hexagonal or circular area with WSN, sensors should also be placed at the centers of hexagon cells to eliminate voids.

The total number of hexagons can be calculated with a known formula for centered hexagonal numbers (4) [31]. Parameter n in formula (4) can be perceived as n^{th} ring of hexagons [32]. As given on Fig. 11, authors place sensors on hexagon vertices and centers to form a hexagonal WSN grid.

Also, a total number of deployed sensors or nodes marked in Fig. 11, is calculated by the equation below [32]:

$$N_{sensors} = a + \sum_{i=0}^{N}(b + c(N - i)d) \quad (11)$$

In (11), N is number of hexagon rings required for the coverage, $a = 7$ as equal to the innermost ring where total number of sensors is 7, b constant in the relation adds 6 hexagons with 4 nodes per hexagon i.e., total number of nodes is 24. Constant $c = 6$, because for each ring, the multiple of 6 hexagons is added. Constant $d = 3$, because for each added hexagon, 3 additional nodes are added.

Another example of embedding hexagonal cells into a hexagonal ROI can be found in WSN clustering example. It is shown that this structure provides better connectivity, where the sensing nodes are deployed at the vertices and centers of each hexagon cell [33]. Fan has shown that calculating not only number of cells in the ROI, but also the cell area in a hexagonal cluster group is interesting [34]. The total number of hexagonal clusters is $6i^2$ and the number of hexagonal clusters in each ring is defined with the following formula, where i is the i^{th} ring from the center [34, 35]:

$$C_i = \begin{cases} 6, & if\ i = 1 \\ 6(i-1), & if\ i \geq 2 \end{cases} \quad (12)$$

There are a lot of benefits for WSN by using hexagonal clusters [36]. The idea of the subdivision, illustrated in Fig. 12 (a), is to divide a hexagonal ROI into a set of smaller sub-hexagon cells, for example a subdivision R/3 into a group of 7 sub-hexagons and 6 third sub-hexagons, which is in total 9 hexagons. Deeper subdivision example is shown on Fig. 12 (b), a subdivision R/4 into 13 sub-hexagons and 6 half sub-hexagons. Authors show that for subdivision R/n total number of equal hexagonal cells is n^2.

5) Hierarchical hexagonal grids: The use of hierarchical grids is common in cartography and biological modelling, where the basic intention is to simplify a grid by reducing its resolution [8]. There are several papers trying to modify the resolution of a grid by decomposing larger cells into smaller ones. Authors describe scaling schemes in which the use of partial hexagons is of interest.

Sahr et al. [37] have shown earlier that a large hexagon cannot be composed of entire smaller hexagons. Hexagonal grids need to have a combination of hexagonal and non-hexagonal composition. As visualized on Fig. 13, one uses 4 hexagons (1 full and 6 border hexagon halves) and the other has 9 hexagons (7 full hexagons and 6 border hexagon thirds).

Ben et al. [38] derived the possibility of ROI rotation. They develop two specific definition schemes for embedding hexagonal grid in the hexagonal ROI (Fig. 14). The approach for the inner scheme is presented also by Kumar et al. [39]. While both former papers provide a model for embedding hexagons into hexagons, no formulas are derived for the total number of inner hexagon cells.

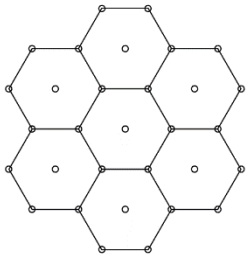


Fig. 11. WSN using Hexagonal Grid Deployment.

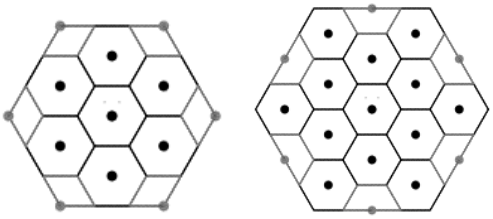
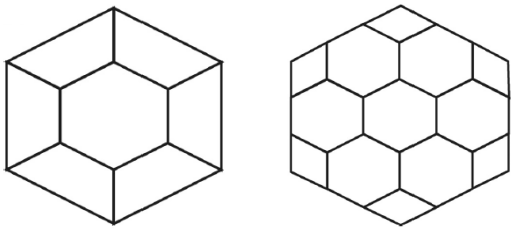


Fig. 12. WSN Cluster Subdivision (a) R/3 (b) R/4 (Adjusted from [36]).



(a) (b)

Fig. 13. Decomposition of Hexagonal ROI in: (a) 4; (b) 9 Hexagons [8, 37].

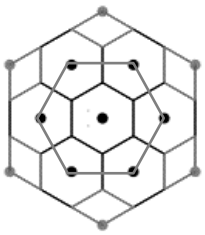


Fig. 14. Embedding Hexagons Into a Hexagonal ROI (Adjusted from [38]).

Sahr et al. [9] calculate the ratios between cell areas at a given grid resolution and the next larger scale grid resolution. They show that N hexagon cells at each finer resolution of a grid have 1/N the area of the next larger grid.

Examples of 1/3, 1/4 and 1/7 fraction are given in Fig. 15. These examples are referred to as centered, meaning that small cells share their centers with larger resolution cells. Vertex-sharing variants are given by [40]. An example of the 1/4 fraction is presented on Figure 15 (d), whereas the vertices are shared among the small and large hexagonal cells.

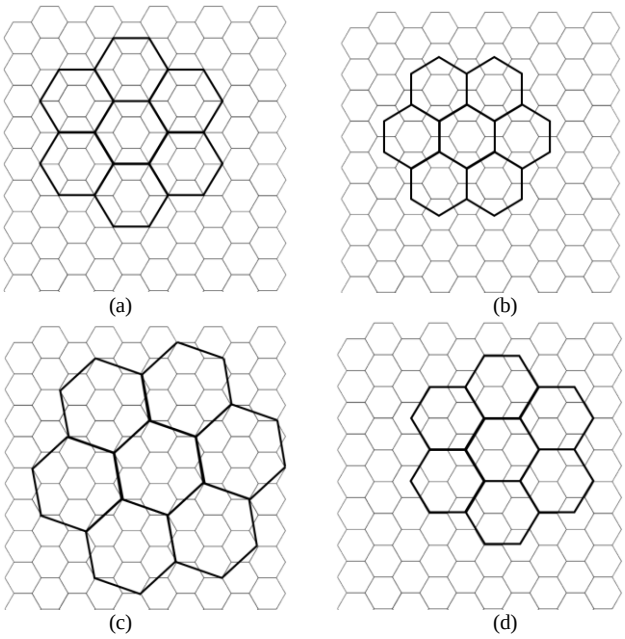


Fig. 15. Hexagonal Resolutions. Center Sharing (a) Fraction 1/3 (b) Fraction 1/4 (c) Fraction 1/7 (d) Vertex Sharing Fraction 1/4 ([9], [40]).

V. Evaluation

The short overview presented in the previous section provides a state-of-the-art on embedding hexagonal cells in the targeted ROI. The literature study revealed the following:

- Each specific application can consider the number of hexagon cells, hexagon vertices and/or centers. In case only vertices or edges are calculated, one can derive the total number of inner hexagons.
- Each application can consider the embedded hexagons to be overlapping or non-overlapping, regarding their total number.
- Inner hexagons can be full or partial ones, especially at the border, and their total number can be calculated separately.
- In some applications, the compromises are considered on the ROI outer border for the cells to be completely contained inside the circular or hexagonal region.

A. Summarized Review Findings

The summarized researches are complemented based on their basic purpose when hexagons are embedded in the ROI. Hence, authors in the papers are:

- Providing models on how to design a specific structural scheme that we are interested in for the CMS geometry application, but with no derived algebraic expressions for calculating the inner cells' total number ([38, 39]).
- Providing formulas for the inner hexagonal cells' number calculation inside a larger hexagon, but:
  - using a well-known formula (1) that is usually applied for the honeycomb network design [22, 24, 25, 34, 35]
  - only providing examples on how to calculate the total number of inner hexagons including the hexagonal parts such as halves of thirds but with no generalized approach [8, 9, 36, 40]
- Calculating the total number of inner hexagons' vertices and/or edges, and the total hexagon number can be derived based on the provided expressions [23, 27-29]

VI. Future Research Directions

A. CMS Detector Design Upgrade

The previously summarized review findings can be used as guidelines for the further studies. The source of research is CMS detector, which is a famous general-purpose instrument for studying proton-to-proton collisions in the Large Hadron Collider (LHC) experiment at CERN [41].

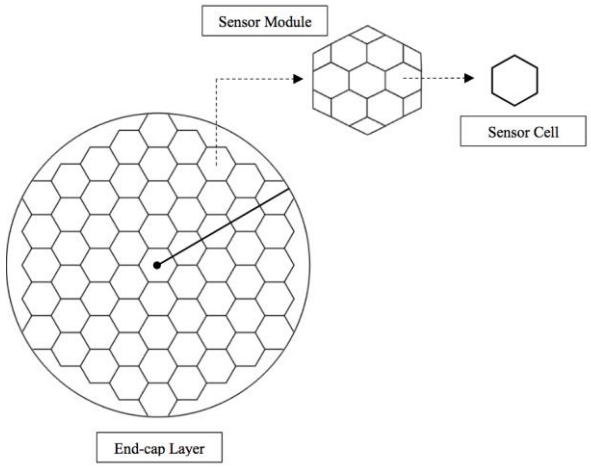


Fig. 16. Hexagonal Structure in the CMS ECAL Upgrade.

Detector is continuously being improved, basically for two main reasons: development of new technologies and replacing parts of the detector which are damaged by very high levels of radiation. In the second phase of the LHC physics program, the upgrades are foreseen by the CMS technical proposal [42]. The most important part of the CMS detector being replaced is electromagnetic calorimeter (ECAL) end-caps since its material gets most damaged by the high levels of radiation. The new sampling ECAL design is proposed, being circular in shape and several layers deep [42]. Each layer should be covered in hexagonal sensor modules (SM) that consist of the inner hexagonal sensor cells (SC) and cover the detector circular end-cap layer (Fig. 16).

B. CMS as a Source for Future Research

As a main future research direction, we are interested in the geometry studies with the aim of the SM design for CMS. The result of the provided literature review enables the overview of the existing models for embedding hexagonal SCs into a hexagonal SM for CMS, which is a hexagonal ROI in the current context. Also, as hexagonal modules are embedded on the circular detector layer, the existing ways of embedding hexagons into a circular shape is interesting. Basic goal of the future study is the calculation of the total number of the inner-ROI hexagonal cells whether circular or hexagonal, to evaluate the embedding efficiency.

VII. Discussion

In Table V, the comparison between papers in the review is given based on the targeted future research. We discuss the potential of applying the state-of-the-art calculations in our targeted application-specific context.

We define several criteria for comparison, such as:

- the total number of hexagonal SCs in the hexagonal SM,
- the total number of hexagonal SMs in the circular detector layer,
- the provided geometrical model for embedding hexagonal grid in the ROI,
- the identification of the partial SCs at the ROI border.

As given in Table V, all selected references provide a possible geometry model for the design of the CMS detector sensing layer. However, not all of them provide the possible formulas for the number of SMs inside a circular sensing region, or the number of SCs in the hexagonal ROI. Even though some basic formulas are derived from the literature findings, there are only few papers in the evaluation part of our conducted review with the potential of having the border SC types identified. Certainly, there is a clear indication for further research on detector sensing layer geometry, in contrast to the summarized review findings. Namely, the total number of inner SCs should be calculated with the objective to estimate the overall SM production cost.

A. Limitations of the Study

Some limitations of the conducted literature survey should be noted. This is a rather short review where we concentrate only on typical applications found in the literature where hexagons need to be embedded in the ROI. There may be other approaches with the similar objective, but we omit it from the review if it does not trigger the potential geometry model for our targeted application. Also, every class of applications in the review could be classified based on various criteria that are application-specific. However, we classify papers only based on the provided formulas used to calculate the number of inner hexagon cells, their edges and vertices. The reason is again the general purpose of the review, to examine the existing formulas on calculating the number of embedded hexagons inside circular or hexagonal area. Also, hexagons can be embedded in other geometrical shapes, while again, the selected ROI shapes are application driven.

TABLE V. Comparison based on the Future Research

Ref.	CMS Geometry Application			
	#SMs inside detector layer	*#SCs inside SM*	*Geometry model*	*Border SCs identified*
[1]	×	×	✓	×
[2]	×	×	✓	×
[3]	×	×	✓	×
[4]	×	×	✓	×
[5]	×	×	✓	×
[6]	×	×	✓	×
[7]	×	×	✓	×
[8]	×	×	✓	×
[9]	×	✓	✓	✓
[10]	×	×	✓	✓
[11]	✓	×	✓	×
[12]	✓	×	✓	×
[13]	×	×	✓	×
[14]	×	×	✓	×
[15]	×	×	✓	×
[16]	×	×	✓	×
[17]	×	×	✓	×
[18]	×	×	✓	×
[19]	×	×	✓	×
[20]	×	×	✓	×
[21]	✓	×	✓	✓
[22]	×	✓	✓	×
[23]	×	✓	✓	×
[24]	×	×	✓	×
[25]	×	✓	✓	×
[26]	×	✓	✓	×
[27]	×	✓	✓	×
[28]	×	✓	✓	×
[29]	×	✓	✓	✓
[30]	×	×	✓	×
[31]	×	✓	✓	×
[32]	×	✓	✓	×
[33]	×	×	✓	×
[34]	×	✓	✓	×
[35]	×	✓	✓	×
[36]	×	✓	✓	✓
[37]	×	✓	✓	✓
[38]	×	×	✓	✓
[39]	×	×	✓	✓
[40]	×	✓	✓	✓

VIII. Conclusion

In this paper, the contribution is threefold. First, we provide an overview on embedding hexagonal cells in the circular and hexagonal ROI, integrating papers from different fields of research. We classify the papers based on the ROI type and the specific application used. We find connections between previous work, concentrating on the need for embedding hexagons into circles or hexagons in the mentioned application-specific context. Next, we report on the existing formulas for calculating the number of inner hexagonal cells, or their vertices and/or edges. Finally, in case only the number of edges or vertices is provided for the targeted application, we contribute by deriving formulas for calculating the number of inner hexagons.

As the overall conclusion derived by our review, there are studies from various research domains dealing with how smaller hexagons can be embedded into larger shapes such as circular or hexagonal region. The importance of calculating the total number of inner hexagons is clearly emphasized in the literature, as well as the potential problems that arise on the outer ROI border in the packing process. Concluded by the conducted review, there exists a theoretical background for the future CMS detector geometry studies, where a hexagonal SM is designed containing hexagonal SCs, and SMs are tessellated on the circular detector sensing layer. Hence, some basic guidelines for the future research on the CMS geometrical structure is provided, together with the existing formulas and algebraic expressions that could be applied or derived from the literature findings. As a next step in our research, we intend to derive a framework of architectures that can be used for the hexagonal SM design, with the aim to efficiently embed the inner hexagonal SCs. The total sensor production cost will be evaluated. Possibly, the solution will be found for solving the problem of packing border cells, at the same time identifying the various sensor shapes that need to be produced.

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Efficient Software Testing Technique based on Hybrid Database Approach

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***Abstract*—In the field of computer science, software testing is referred as a critical process which is executed in order to assess and analyze the performance and risks existing in software applications. There is an emphasis on integrating specific approaches to carry out testing activities in an effective mode; the efficient strategy being explored recently is adopting hybrid database approach. For this purpose, a hybrid algorithm will be proposed to ensure the functionality and outcomes of testing procedure. The technical processes and its impact on current methodology would help to evaluate its effectiveness in software testing through which specific conclusions could be drawn. The findings of the research will elaborate effectiveness of the proposed algorithm that would be used in software testing. It would be suggested that new technology is easier and simple to assess and analyze the reliability of the software. Basically, hybrid database approach comprises of traditional and modern techniques that are deployed in order to achieve testing outcomes. It is explored from various testing methods that challenges have been identified related to focusing on traditional techniques due to which hybrid approach is now being developed in most of the areas. In the light of addressing these concepts, the paper aims to investigate the complexity and efficiency of hybrid database approach in software testing, as well as its scope in the IT industry.**

Keywords*—Software testing; database testing; hypothetical database testing; traditional database testing; test case(s); grey box testing; software quality assurance

I. Introduction

Computer science is a vast field which is distributed across innumerable sections in order to address different technicalities. Software testing is one of the fields in Computer Science which is referred as incorporating critical processes for assessing and analyzing possible risks and performance of a software [1]. A number of professional software testers across the world have explored variety of mechanisms that are performed to test vulnerabilities, as well as the efficiency which are the core areas of software testing. In the recent IT industry, the major concern that software developers and testers have reflected is the incompetent approaches being applied in the field of testing that hinders functionalities while business needs are not appropriately catered as they should be [2].

The IT industry has always performed strategically in providing utmost facilities to the business so that no technical issues could affect their performance and productivity [3]. In every day technical activities, a number of software techniques are adopted and used according to the specifications so that significant outcomes could be met. However, difficulty is faced when appropriate methods are not satisfying technical needs due to which businesses are affected at large [4]. All of these professional ensure that developed software are bug-free because they follow specific software development life cycle in order to make sure that each component of the software is developed under full consideration. Among these phases, software testing is also applied which is actually performed to assure quality and necessary fixes that are done to improve its functions [5].

Nowadays, reliable software development needs are not properly reviewed due to which businesses, as well as consumers, are facing difficulty in taking benefits from its use [6, 7]. Software testing has been given more attention in every aspect but due to outdated methods and techniques, certain technical needs are not properly fixed. In this regard, concerns have been placed to improve traditional methods by integrating modern approaches in order to improve software testing approaches. In the current methods, database approach is getting more attention due to its reliability and efficiency to fulfill testing needs thus, hybrid approaches have become research's focus recently. The following study is developed to address the need to overcome the problem(s) and introduce hybrid approach in software database testing [8, 9].

A. Paper Structure

Section II presents a brief description of utilization of software testing methodologies along with their key research contributors under the umbrella of literature review. Section III put forward the proposed software testing methodology based on hybrid database approach. Section IV emphasizes more specifically on the algorithm and execution of proposed software testing approach in an illustrative manner with a brief on limitations of the study. Section V and Section VI compares the performance of proposed methodology with the methodology based on traditional database testing approach by considering various parameters for testing goals and its accomplishment. Section VII concludes the proposed methodology better than the traditional approaches in terms of performance and foresees more refined methodologies even better. It also foresees future aspects of this research in terms of quantum computing and machine learning perspectives.

II. Literature Review

A. Software Testing

According to Bajaj, Kamini Simi [2], the process of software testing is not complicated but its approaches have increased its complexity to the greatest extent. The author further sheds light on the definition of software testing in terms

of evaluation process in which the software is tested to ensure whether it is developed to meet system originality or not. Furthermore, the author also adds that the process of software testing comprises of validation and verification aspects that checks if the developed software is meeting certain criteria defined by the user [10]. The analysis of the study determines another important part of software testing which include results that defines the major difference between actual and expected result.

B. Existing Testing Methods

In software testing, the pre-defined traditional methods are recognized in almost every technical area and thus, their functionalities and approaches varies with the level of testing method. Based on the study of Arnicans, Guntis, and Vineta Arnicane [5], fundamental software testing methods incorporated in every aspect are black box testing, white box testing, and grey box texting. Different forms of database testing types and techniques have already been developed that are being preferably used according to the suitability and applicability of the specific type of database on a specific platform. The generally discussed types of database testing techniques are in the form of structural (internal) database testing, non-functional (external) database testing and functional (logical / conceptual) database testing [11, 12].

C. Black Box Testing

The paper proposed by Jamil, Muhammad Abid, Muhammad Arif, Normi Sham Awang Abubakar, and Akhlaq Ahmad [1] describes that black box testing only performs testing measures in evaluating software's functionalities rather than focusing on its implementation in detail. It is identified that black box software testing is appropriate at every level of SDLC in order to examine the bugs and errors within major functionalities. The basic function of the testing method is to assess the required functions and compares it with user requirements to verify if the application is developed according to desired needs [13, 14]. The following existing method is efficient in finding adequate functionalities by testing each phase at their minimum and maximum case value. Jamil, Muhammad Abid, Muhammad Arif, Normi Sham Awang Abubakar, and Akhlaq Ahmad [1] also explain that black box testing is one of the simplest and widespread methods which are mainly carried out by professionals across the globe.

D. White Box Testing

Muşlu, Kıvanç, YuriyBrun, and Alexandra Meliou [3] define the significance of white box testing in terms of its effectiveness and important functions. Basically, white box testing is one of the approaches that are famous for testing internal structure of the developed software. It is also evident that to perform white box testing, IT industry requires specific programming skills and knowledge as a pre-requisite in order to develop test cases. Another study provides more information regarding white box testing [15]. In the study, the method is also illustrated as clear box or glass box testing due to the fact that it validates and verifies internal mechanism to satisfy development process. In addition, white box testing is also known to be applied to different levels, such as unit, integration, and even system testing. It is also explained that among all other testing methodologies, white box testing is excellent due to its nature and complexity [16].

E. Grey Box Testing

With respect to grey box testing, Arnicans, Guntis, and Vineta Arnicane [5] define that it is hybrid in nature because it accompanies all the basic requirements and functions that are performed by black box and white box testing. As the approach carries advantages of both black box and white box testing, grey box testing is vitally used across different areas in order to evaluate vulnerabilities and security of the developed software. Inputs are provided from the front interface of the application in order to verify back-end data structure through debugging process which reveals internal culpabilities of database schema [17].

III. Proposed Methodology

To display the functions and phases of testing, following research proposes an algorithm for hybrid software testing database approach which can be used to develop an efficient and effective testing methodology for software developers [18]. Secondary sources are used to collect specific information regarding testing methods and emergence of new technology. For this purpose, different scholarly articles and tech blogs were reviewed. The research is designed on the basis of addressing technical processes and its impact on software development to ensure the effectiveness and efficiency of designed procedure. Illustrated "Fig. 1" beneath depicts the proposed methodology [19].

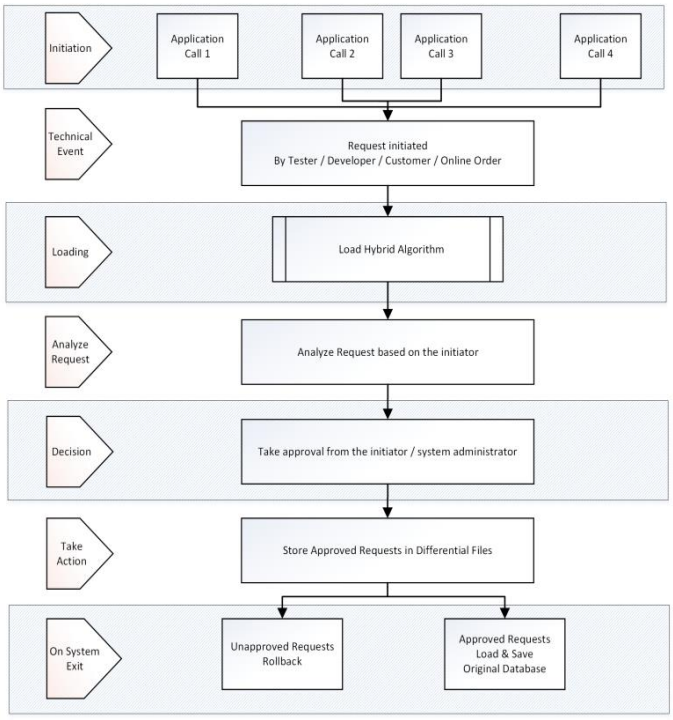

Fig. 1. Proposed Methodology.

IV. Hybrid Database Approach

It is evident from recent studies that mode of testing practices are changing due to the software preferences, as well as concerns regarding quality. A new way of to test software applications have been proposed but limited information and significance is available to prove its efficiency. As illustrated in the study by MM Baig [20, 21, 22], database approach is one of the effective ways that provides new features to current testing methods in order to evaluate the performance and risks of the software by building effective test cases. It is also examined that by using hybrid technology, the upgraded features enable developers to assess improved quality of the application while it reduces amount of critical bugs in the application. Moreover, the proposed methods are also effective in terms of providing early information regarding issues that might affect performance of software while deviate its results from the expected outcomes [23].

An algorithm to execute hybrid testing method is proposed which is said to be more efficient and reliable as compared to traditional and hypothetical database testing method. In the process, when a request is generated by the initiator the algorithm analyzes it and based on the evaluation different states are maintained prior loading it into the original database [24, 25]. Treatment of initiated request(s) is as follows:

1) Request initiated by end user / customer / online order: Requests generated by Customer(s) and Online Order(s) are by default approved and original database are updated as per traditional way on reaching timestamps defined for the system.

2) Request initiated by Developer(s): Requests generated by developer(s) are treated through hypothetical database testing method in which a new database state would be generated, known as hypothetical database while it is ensured that the originality of the previously generated database is intact. This is due to the association established between the original database and differential table subject to approval from developer(s) side. Changes in the schema made by the developer can easily be implemented on the primary database at day end after stoppage of daily transactions.

3) Request initiated by Tester(s): When a tester executes a test case(s), the results will be displayed in the grid and will be viewed to tester only. If required these can be saved in differential files related to testing for future correspondence else they will be rolled back when the tester exits the system. This would be done in order to facilitate different anomalies that could be performed through differential file on hypothetical database states. The traditional approaches were using these anomalies on original databases which are inappropriate as its originality would be affected due to which tester face problems in analyzing actual requirements.

By referring to "Fig. 2", it can be viewed that tester implements first test case which is being analyzed by the hybrid algorithm which contains an instance of the primary database state. When the test case is successfully completed at this level, the updated results will be stored in differential file containing differential table ensuring that the originality of the primary database is not intact. When the second test case is run, same procedure will be followed. After execution of entire test suite if the desired results need to be stored in the original database with tester's login for future referencing it is possible only after approval. All the unapproved request(s) will be rolled back automatically [26, 27, 28].

In "Fig. 3" below, state transition diagram is illustrated which is based on different states. From the illustration, it can be viewed a transition will occur on the fulfillment of requirements by the hybrid database instead of original or hypothetically generated database. From the analysis of the following method, it is suggested that hypothetical rollback can be performed to any state rather than executing the action on the original database [29]. However, the time complexity of the roll back is quite efficient as it quickly reaches to the destination state as compared to traditional ways. With the fast and efficient approach, processing time is minimized, while costing and budgeting of the whole method is also reduced. Based on the proposed plan, the algorithm of testing includes number of test cases while test case generates number of differential tables in differential files. In the next step, software tester would be required some time to prepare more test cases as the previously generated cases are not appropriate by current database states in the hypothetical chain [30, 31].

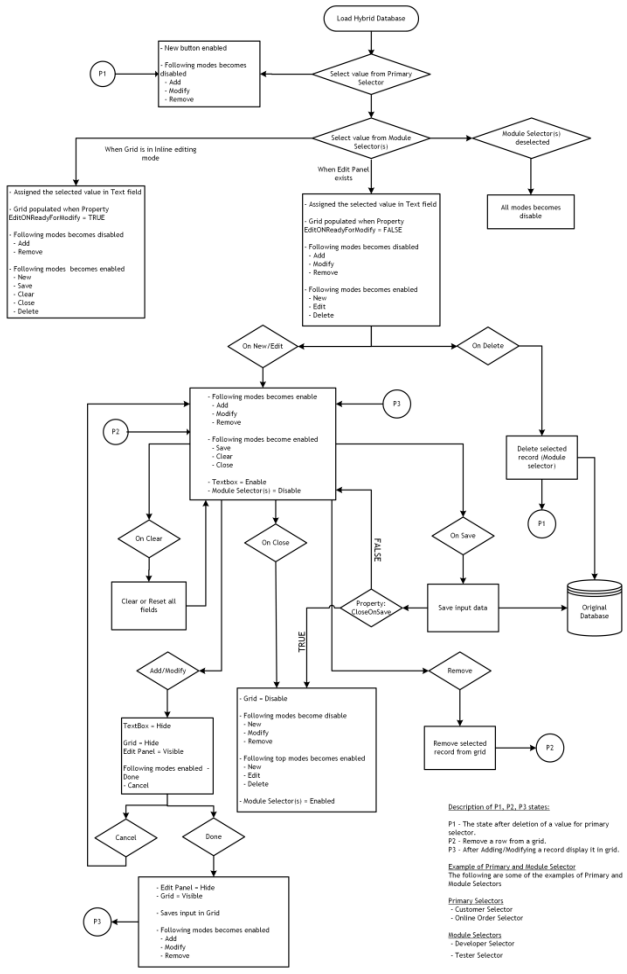

Fig. 2. Hybrid Database Approach.

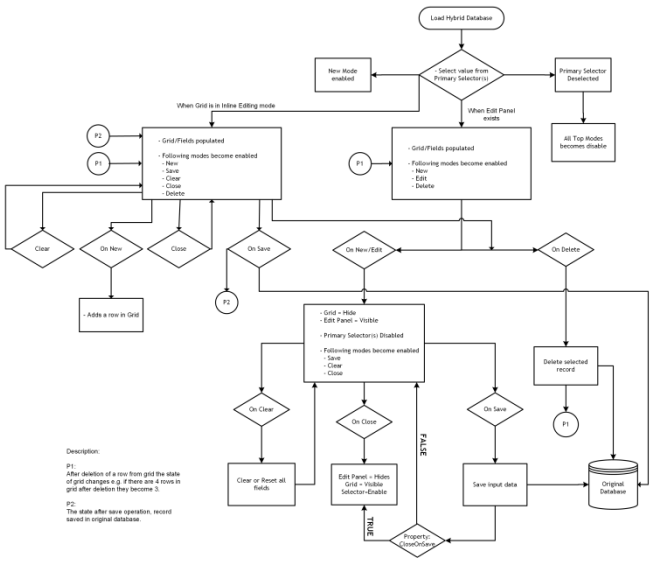

Fig. 3. State Transition Diagram.

State transition illustrated above completely elaborates the mechanism that a tester would be following in order to achieve desired results. In the following situation, another concept would be proposed in order to fix the state while new generated databases would comply with the established standards. The concept of database rollback will also be used in the following situation in order to let generated databases fulfill conditions of developed test cases. The main purpose for using the option in current testing methodology is that it increases efficiency of the database generation while the preparation time of current state is improved [32, 33].

A. Hybrid Database Testing Algorithm

HYBRID DATABASE TESTING ALGORITHM[1] to propose hybrid plan is detailed in "Fig. 4" beneath.

Algorithm 1: HYBRID DATABASE TESTING ALGORITHM

```
Result: Efficient Software Testing using Hybrid Approach
Initialization: Load data in Hybrid Schema
Parameters: Pass Initiator reference and Request (Test Case / Query / Transaction)
BEGIN
 INPUT v_initiator_id, v_request_str
  SWITCH (v_initiator_id)
    CASE 'Tester':
        Create a Differential File;                    // for tester
        Execute Test Case v_request_str;
        Store result in Differential Table;
        Check State: Exit / Timestamp Reached
            Ask for approval
            If 'Approved' then
                    SAVE in Primary Database
            Elseif 'Partial Approved' then
                    Store Result in Hypothetical Database through Differential File // for future reference
            Else
                    ROLLBACK
            End
        BREAK
    CASE 'Developer':
        Process v_request_str;
        Create a Differential File;                    // for developer
        Store schema change;
        Check State: (Exit / Timestamp Reached) and (No user is login to the system)
            Ask for approval
            If 'Approved' then
                    UPDATE Primary Database Schema
            Elseif 'Partial Approved' then
                    Store Result in Hypothetical Database through Differential File // for future reference
            Else
                    ROLLBACK
            End
        BREAK
    CASE 'End User':
        Process v_request_str;
            If DATA is structured then
                    UPDATE Primary SQL Database Schema
            Else
                    UPDATE Primary NoSQL Database Schema
            End
        BREAK
    DEFAULT: Store Result in Hypothetical Database through Differential File // for future reference
 END SWITCH
END
```

Fig. 4. Hybrid Database Approach Algorithm.

B. Roadmap towards Hybrid Database Testing

The strategy to propose hybrid database testing plan is elaborated in Table I below.

C. Limitations of the Proposed Study

Different challenges are associated with database testing due to nature of databases which is complex both structural-wise and magnitude-wise. Testers skill set ascends a handful of challenges related to designing of test cases and the tactics to execute them with proper exploration. Core challenges were related to database schema structure, cleansing / synchronization / reliability of quality data and under-testing / incomplete testing of colossal database. However, efforts were made to overcome these issues in the proposed plan so that more effective method could be developed.

TABLE I. HYBRID DATABASE TESTING ROADMAP

	Description
OBJECTIVE	To perform database testing in order to uncover incomplete schema, malfunctioned functionalities, data corruption, deadlocks, data mapping issues and exceptions.
TESTING CRITERIA	Testing of all key database schema tables, methods, processes, sequences, functions, indices, views, cursors, triggers and stored procedures.
PRE-REQUISITES	Testing requirements are well communicated / well documented to testers. Test cases covering all aspects of database testing are designed. Success criteria have been established prior testing phase. Test environment is setup and freeze with latest database schema.
EXCEPTIONAL CONTEMPLATION	Testing conducted with real time data on actual environment. Automatic invocation of stored procedures and processes. For large databases DBMS Development Environment is required to populate data directly into the database from backend in order to monitor its frontend adaptation. For small sized databases limited records are generated to test non-acceptable events / triggers / exceptions.
TESTING TECHNIQUE	Selection of testing technique / strategy is based on the fact it must support the testing of all key use-case scenarios and complete business flows i.e. main features.
REQUIRED TOOLS	➢ Test Management Tools ➢ Test Script Automation Tool ➢ SQL Query Analyzer ➢ Test Data Generator ➢ Bug Tracking tool ➢ Backup and Recovery tools
PROCEDURAL STEPS	Testers will work according to the database testing checklist and guidelines to inspect the database ensuring proper data for correct reasons is inserted and stored in the database.
POST-REQUISITES	Execute each test case separately but sequential using valid and invalid data should reveal expected results for valid data and timely error messages to refrain insertion of invalid data in the database.

From the above algorithm, proposed strategy and limitations it is deduced that existing methods are inefficient and provides limited access to basic software testing which is why appropriate results are not achieved. By using hybrid software testing database approach, software developers and testers would gain more assistance in testing phase while there will be the exceptions for increased bugs and incidents. Moreover, it is considered as efficient while performance is also adequate because of less time consumption, cost-effective and limited resource utilization. This algorithm is not only convenient but also gives easy access to acknowledge basic requirements that must be present in developed software [34].

V. Results with Discussion

To check the efficacy of the algorithm it multiple queries and test case(s) were designed and run on the schemas separately in order to monitor their performance. Results of both queries and test case(s) are discussed below.

A. Query Processing Time

Multiple queries as illustrated in "Fig. 5"were designed as per the following types: Aggregate Queries ($Q_1 - Q_{50}$), Join Queries ($Q_{51} - Q_{100}$) and Nested Queries ($Q_{101} - Q_{150}$) where "$Q_{\#}$" is used to represent "Query $_{number}$". These queries were run on a sample database of following size(s): 400 MB, 4 GB, 40 GB and 400 GB. Due to classified database architecture and complex confidential queries only general queries related to student database are being shared in "Fig. 5"for assistance.

To analyze the processing time in seconds these queries were first executed through the traditional database testing approach, secondly through hypothetical database testing approach and lastly through hybrid database approach. According to the results shown in Table II below, it can be concluded that the processing time of the queries illustrated in "Fig. 6", "Fig. 7" and "Fig. 8" has greatly reduced approximately 70% with the use of hybrid database approach as opposed to accessing the data directly.

```
00 public class Hybrid_Research_Experiment {
01 private int initiator_ID;
02 private string initiator_Request;
03
04 Sub Hybrid_Schema_Access(ByVal vinitiatorid As Int64, ByVal vinitiatorreq As str)
05
06 {
07
08 '  Aggregate Query Example Q1 - Q50
09 '  Sample Q1
10 queryResult = QueryRunner.Run {
11     "SELECT SUM(marks) "Total" " +
12     "FROM resultTab"
13     }
14
15 '  Join Query Example Q51 - Q100
16 '  Sample Q65
17 queryResult = QueryRunner.Run {
18     "SELECT a.studentID, a.deptno, b.dname" +
19     "FROM student a RIGHT OUTER JOIN dept b" +
20     "ON (a.deptno = b.deptno)"
21     }
22
23 ' Nested Query Example Q101 - Q150
24 ' Sample Q145
25 queryResult = QueryRunner.Run {
26     "SELECT studentID," +
27     "(SELECT studentname FROM student b WHERE b.studentID = a.teacher) Instructor" +
28     "FROM student a" +
29     "ORDER By teacher"
30     }
31  }
32 End Sub
```

Fig. 5. Sample Query Architecture.

TABLE II. Query Processing Time recorded on different schemas

Query Processing Time				
Query Types	***Database Size***	**Processing Time Recorded**		
		Direct Schema	***Hypothetical Schema***	***Hybrid Schema***
Aggregate Queries ($Q_1 - Q_{50}$)	400 MB	≈ 300 s	≈ 180 s	≈ 60 s
	4 GB	≈ 720 s	≈ 420 s	≈ 90 s
	40 GB	≈ 900 s	≈ 720 s	≈ 120 s
	400 GB	≈ 1320 s	≈ 1140 s	≈ 300 s
Join Queries ($Q_{51} - Q_{100}$)	400 MB	≈ 420 s	≈ 300 s	≈ 120 s
	4 GB	≈ 900 s	≈ 600 s	≈ 240 s
	40 GB	≈ 1080 s	≈ 840 s	≈ 300 s
	400 GB	≈ 1500 s	≈ 1200 s	≈ 480 s
Nested Queries ($Q_{101} - Q_{150}$)	400 MB	≈ 480 s	≈ 240 s	≈ 180 s
	4 GB	≈ 1020 s	≈ 720 s	≈ 360 s
	40 GB	≈ 1200 s	≈ 900 s	≈ 540 s
	400 GB	≈ 1620 s	≈ 1200 s	≈ 600 s

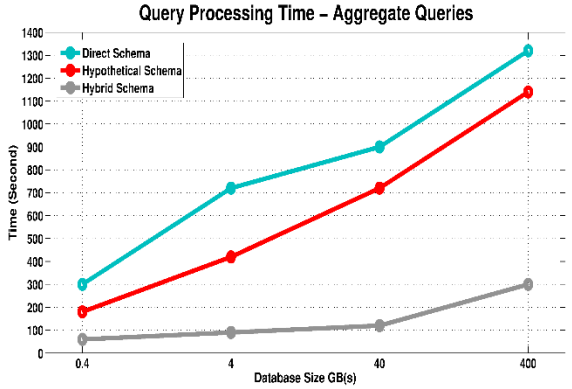

Fig. 6. Aggregate Queries Processing Time.

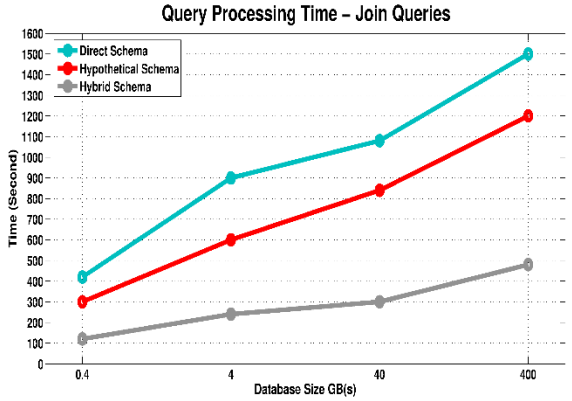

Fig. 7. Join Queries Processing Time.

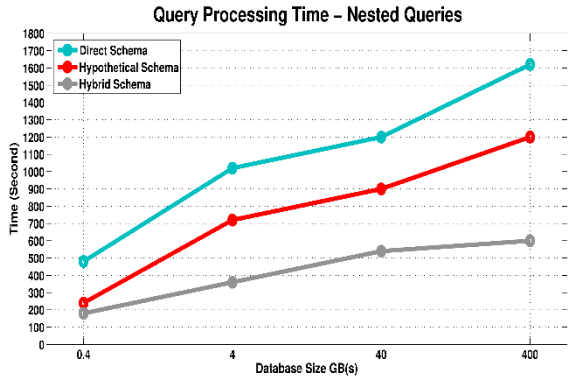

Fig. 8. Nested Queries Processing Time.

B. Test Case(s) Execution Time

Test Case(s) Matrix as per "Fig. 9" was designed and executed on the database schema designed hypothetically and hybrid in addition to direct database schema. To check the functional aspects of database "Functional Test Case(s): TC_1 – TC_{50}" and for non-functional aspects "Non-Functional Test Case(s): TC_{51} – TC_{100}" were designed where "$TC_{\#}$" is used to represent "Test Case $_{number}$". These test cases were run on the same sample database of size(s): 400 MB, 4 GB, 40 GB and 400 GB used for query execution.

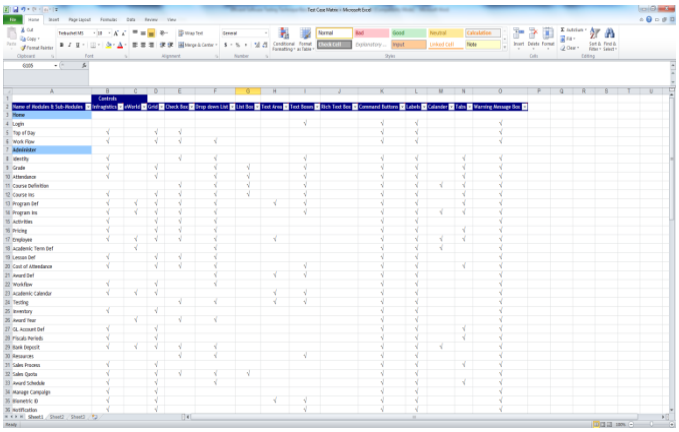

Fig. 9. Test Case Matrix.

To analyze the execution time in minutes these test case(s) were first executed through the traditional database testing approach, secondly through hypothetical database testing approach and lastly through hybrid database approach. According to the results illustrated in Table III below, it can be concluded that the overall execution time of test case(s) as shown in "Fig. 10" and "Fig. 11" almost reduced to 60% of the actual processing time required to execute the test case(s) directly on the primary database.

TABLE III. TEST CASE(S) EXECUTION TIME RECORDED ON DIFFERENT SCHEMAS

Test Case(s) Execution Time				
Test Suites	***Database Size***	**Execution Time Recorded**		
		Direct Schema	***Hypothetical Schema***	***Hybrid Schema***
Functional Test Cases (TC_1 – TC_{50})	400 MB	≈ 15min	≈ 11min	≈ 5min
	4 GB	≈ 20min	≈ 16min	≈ 8min
	40 GB	≈ 33min	≈ 25min	≈ 18min
	400 GB	≈ 45min	≈ 31min	≈ 23min
Non-Functional Test Cases (TC_{51} – TC_{100})	400 MB	≈ 18min	≈ 10min	≈ 4min
	4 GB	≈ 22min	≈ 11min	≈ 7min
	40 GB	≈ 38min	≈ 27min	≈ 15min
	400 GB	≈ 56min	≈ 35min	≈ 21min

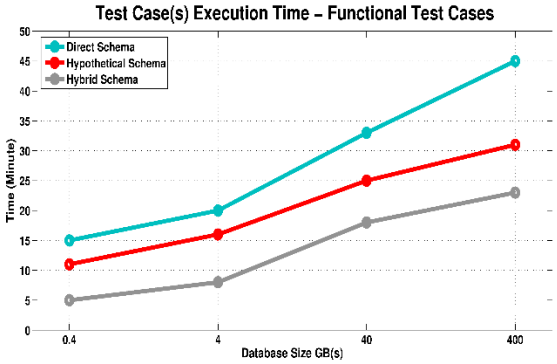

Fig. 10. Functional Test Case(s) Execution Time.

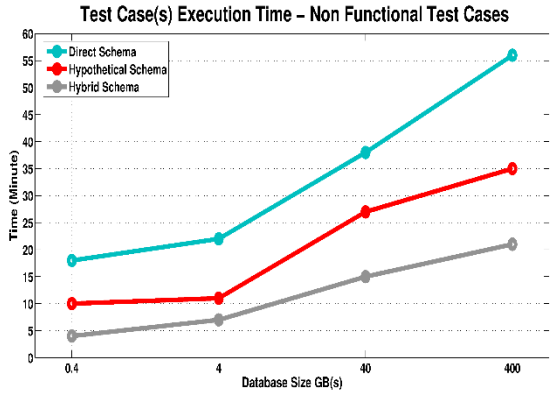

Fig. 11. Non - Functional Test Case(s) Execution Time.

VI. Testing Goals Achieved

Testing goals which were achieved are listed as:

1) Normalization rules: No data was repetitive in the database and all columns were logically connected.

2) Data types: As the systems are taking data in dynamic nature, deciding the type of data columns is very crucial. In some scenarios, you can expect some extremely weird inputs which are important. Make sure the data is going into the right columns and cells. This thing is taken care very seriously as a mismatch of the columns can cause huge issues in the stability of the database.

3) Retrieval of data and number of joins: Usually, developers avoid adding multiple joins or making query complex mainly because of the system's speed and its response time.

4) Data endpoints: It always checks the data populating the database from the system v/s data generating by the database for the database (triggers or metadata).

5) Usage of the flag: For the system to work properly, mainly columns worked as a flag for a different thing. e.g. 0=admin user, 1= Developer, 2 = Tester etc. This is also tested seriously to control the access level permissions.

6) In some big systems: we also test the write speed. Sometimes, the data coming to the database is huge, and the database is not keeping up the phase. So the threshold was also tested. Mainly it happens in ecommerce website where user actions and activities are also recorded against their profile.

7) Database security and password encryption issues.

8) Online testing of software application in parallel with order processing or daily transactional operations without the use of separate test environment was possible with add-on functionality of roll back.

VII. Conclusion and Future Work

During software development, it becomes quite difficult for the developers and testers to identify the bugs and required test case(s) that are needed to be executed to achieve actual results. Hybrid Database testing approach was formulated and tested with execution of queries and test case(s) on sample database(s) of sufficient sizes reflecting the achievement of testing goals in an efficient manner. Using the proposed hybrid plan, businesses would improve in terms of using effective software testing methods without creating separate environments that would cause them to invest little while productive results are achieved. It is also acknowledged that complexity and time-consuming activities in recognizing errors in the software testing phase can be easily managed due to the flexibility it provides in searching and updating records in the primary database without keeping it intact during the whole course of time. Assessments of requests generated from different initiators can also be processed simultaneously with segregation as per requirement.

Moreover, in future, it is anticipated and expected to witness software testing tools being developed with build-in features of hybrid state transition between databases with integration of quantum technology and machine learning techniques. In software testing that would include different processes in order to provide accurate and unambiguous results in even lesser time. As the new technology is becoming famous in IT industry, it is expected to see more transformations in the field of software testing due to which traditional approaches would be diminished while integration of hybrid technologies would be seen.

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Agile Methods Selection Model: A Grounded Theory Study

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***Abstract*—Agile methods adoption has increased in recent years because of its contribution to the success rate of project development. Nevertheless, the success rate of projects implemented using Agile methods has not completely reached its expected mark, and selecting the appropriate Agile methods is one of the reasons for such lag. Selecting the appropriate Agile methods is a challenging task because there are so many methods to select from. In addition, a lot of organizations consider the selection of Agile methods as a mammoth task. Therefore, to assist Agile team members, this study aimed to investigate how the appropriate Agile methods can be determined for different projects. Based on a Grounded Theory study, 23 Agile experts drawn from 19 teams across thirteen countries were interviewed. Hence, this study employed the Ground Theory of selecting Agile methods. Sixteen factors, grouped into five categories, have been found to affect the selection of twenty Agile methods. The nature of project (size, maturity, criticality and decomposability), development team skills (communication skills, domain knowledge, team technical skills and maturity), project constraints (cost/value/ROI, cost of change, time, scope and requirements volatility), customer involvement (collaboration, commitment and domain knowledge) and organizational culture (type of organizational culture) are the key factors that should guide Agile team members in the selection of an appropriate Agile methods based on the value these factors have for different organizations and/or different projects.**

Keywords*—Agile methods selection; factors; model; grounded theory analysis

I. Introduction

Majority of companies are inclined towards implementing effective quality systems in a timely manner through reasonable costs [1]. This is the reason of such companies shift towards Agile methods, and in this regard, it has been revealed that different factors have to be considered when selecting Agile methods [2]. The selection for different projects should be according to the nature of projects, development team proficiency, organizational culture, customer involvement and project constraints considering several alternative Agile methods, Consequently, although the Agile methods use are increasing in software development projects, there are still firms that look upon the selection of a suitable Agile method as a great insurmountable challenge. Moreover, to compound this issue, studies dedicated to the difficulties related with the Agile methods effective selection are still few and far between [2, 3].

Therefore, This is expected to help the members of the Agile team to select the most suitable Agile methods based on different project conditions to guarantee that that the results are successful. Accordingly, a grounded theory study was conducted to investigate how the factors that influence the selection of Agile methods can assist Agile team members in such selection.

The remaining parts of this paper is organized in the following way; in Section 2, the Agile methods background and the related techniques are discussed, and in Section 3, the research methodology used in the study to examine the selection of Agile methods is presented. This is followed by Section 4 that contains the results from the grounded theory study, and Section 5 that provides the Agile methods selection model. Lastly, in Section 6, the conclusion and future studies scope are enumerated.

II. Related Work

In this section, the author provides a brief overview of the background of Agile methods and the major methods utilized for their selection. In this regard, a group of 17 software developers came together to work towards enhancing system development methods in 2001. They brought forward the Agile methods that have their basis on four values and twelve principles under the Agile Manifesto. Specifically, the four values lay stress on individuals and interactions, working software, customer collaboration and change response [4]. The Alliance also fine-tuned the values encapsulated in their manifesto into twelve principles in order to assist developers and project managers to understand the Agile methods and the application of their values. Some examples of the principles are listed as follows [4].

1) Face-to-face conversation is the most effective and efficient method of conveying information.

2) Welcome changing requirements at any stage of the development.

3) Self-organizing teams are very important for software development.

4) Simplicity is essential

Over the years, different Agile methods and practices have been developed to cover and achieve the above principles. For instance, different Agile methods focus on the principle of having face-to-face conversations (principle 1 above). On the other hand, XP method focuses on keeping the design of the system very simple to be able to maintain and quickly revise (principle 4 above). Kanban also limits work in progress to achieve simplicity (principle 4 above), so there is a possibility

of changing the requirements at any stage of the development (principle 2 above), while, collective ownership is an Agile modeling practice that focuses on assisting each team member to work on any model and manage the work with other team members as a group (principle 3 above).

In the current times, several Agile methods can be used and this added to the difficulty in the selection of the most suitable one to use in specific contexts [2]. In addition, organizations find it difficult to employ the same method for all their projects implementation owing to the varying requirements of every project [5]. Also, there is no single Agile method that is capable of solving all the issues of the organization [3]. Examples of Agile methods include Kanban [6], SCRUM [7], Crystal family of methods [5] and XP [8]. Therefore, there is a necessity for discerning a way to ensure that the top suitable Agile methods are selected to suit specific projects [2]. Hence, researchers and practitioners have begun examining different selection techniques for the most appropriate Agile method to use for a specific project. Examples of the selection methods that have been proposed in literature can be found at [2]. However, examples of the current selection methods are listed as follows:

- Sayed et al. (2017) proposed a method for Agile methods selection using Analytic Hierarchy Process (AHP). Positive response in dynamic requirements, communication with the customer, incorporation of requirements changes, and the size of development team were the main factors that should be considered in the selection of Agile methods [9]. However, the selection was for Institute Examination System project and crystal family and Agile Modeling methods were the most appropriate methods for this project.
- Sharma et al. (2017) proposed a framework for Agile Development Method Selection using multi-criteria decision making. The researchers used Modified PROMETHEE with Analytic Hierarchy Process to select the appropriate method among six Agile methods (Lean Software development, DSDM, XP, Scrum, Crystal Clear and FDD [3]. Formalization and documentation, reluctance to change, practices overhead and project reliability and scalability were the main factors that should be considered during the selection. This kind of methods, by the use of matrices, require experts' knowledge of the suggested alternative to be able to select the appropriate methods [10].

III. Research Methodology

Prior studies in literature show the necessity to examine the Agile methods selection but as yet, no empirical findings have been reported on the demonstration of selection processes of Agile methods based on the values of an integrated selection factors. Therefore, the main objective of this study is to conduct an empirical study to investigate how the appropriate Agile methods can be determined for different projects and/or different teams in different organizations. Although the qualitative approach comprises of several research designs, there are five common qualitative research designs, and they are case study, ethnography, content analysis, grounded theory and phenomenological study. The present study used the grounded theory as the researcher found it to be the most suitable method to use to answer the research question of the research. The main reasons of conducting a GT are as follows:

1) Grounded theory is a qualitative research method, which allows the researchers to understand social interactions and behaviors. Agile methods are all about people and interactions [11].

2) Previous studies demonstrates that the selection of appropriate Agile methods was not explored in detail [3]. So, grounded theory is destined for that [11].

3) Grounded theory helps in producing theory rather than extending or verifying extant theories in what is referred to as an interesting and new prospective.

4) Grounded theory is used when examining new themes and areas and when providing a new view into an established phenomenon.

As will be explained below, a total of 23 interview have been conducted with Agile experts concerning Agile methods selection. The following sub-sections present descriptions of the GT procedures applied in this research.

A. Data Collection (Interviews)

The present study adopted semi-structured in-depth interviews with open-ended questions to help the researcher to obtain and understand the views, experiences, perceptions and viewpoints of the interviewees on Agile methods selection. Twenty-three experts were chosen from different organizations from different countries.

The 23 participants were experienced in using different Agile methods, and 20 Agile methods were noted to be used in different organizations by the participants. The methods were reported with clarification on how they have been selected.

B. Data Analysis

Grounded Theory (GT) approach was employed in data analysis. It was employed for the identification of processes and factors affecting Agile methods selection. In addition, it assists in understanding how different selection factors can be used in the selection of Agile methods. The researcher employed three coding techniques established by GT approach namely, open coding, axial coding and selective coding to analyze qualitative data [12]. Following the assignation and creation of open code, lists of open code are categorized on the basis of their codes relationship and connection. Project size, Maturity and criticality are examples of the initial codes. Axial coding process groups general categories in open coding under higher ordering headings in order to minimize the number of categories by combining similar and dissimilar into general categories. For instance, project size, maturity and criticality fall under the nature of project. Moreover, selective coding process identifies the core category that relates to the gathered data, and such core category functions as the hub for the rest of the other identified categories. For instance, that project constraints is among the main core-categories consisting of scope, time, quality and cost/value/ROI as categories, and requirements volatility and cost of change as sub-categories.

IV. RESULT

In the following sections the results will be reported to present Agile methods Selection theory. The results involved the analysis of the results retrieved from the interviews. That is, how the appropriate Agile methods can be determined for different projects and/or different teams in different organizations. Agile methods selection model illustrates the factors that have been found to affect the selection of an Agile methods. Each method can be used for different projects in different situations. The explanation including examples of the statements that have been obtained from the respondents are described in the next sections as follows:

A. Nature of Project

Projects are not the same in size and in criticality and as such, no single Agile method is appropriate for all organizational issues [5]. In other words, the project nature (size, maturity, criticality and Decomposability) has to be examined and kept into consideration during the selection of Agile methods.

1) Project size: The analysis revealed that project size, in many ways, influences the selection of Agile methods. With small project size (less than 10 stakeholders), XP, SCRUM, Crystal Clear, DSDM and Kanban are preferred. This is because methods such as, XP and SCRUM allow the small team to work together face-to-face when developing a project:

R13 (Project Manager): "We make a small team to do the work and we separate the tasks for them and we found DSDM and Kanban to be suitable."

R14 (Chief Knowledge Engineer): "SCRUM, Crystal Clear and XP work fine for small teams because you do not need extra collaboration and extra communication."

However, with medium project size (10 to 100 stakeholders), scaled method such as SCRUM of SCRUM, LeSS, Nexus and Crystal Red could be more appropriate:

R10 (Senior Consultant): "For big product groups, like 8 groups with eight people in each group, we can use LeSS Framework or Crystal Red. I can also use Nexus"

R8 (Director of the Agile Organisation): "SCRUM of SCRUM is directly scaled for about 20, 30 or 40 stakeholders, without needing something else."

If one group of people is working on a single large project (above 100 developers), then scaling methods such as DAD, SAFe, Nexus+ and Spotify scaling methods, are appropriate as they could be used for a large group of people. Additionally, they are appropriate for large projects since there is a need for initial planning to solve dependencies issue and more architecture for the same issue, including which team understands what to implement exactly.

R10 (Senior Consultant): "I also consider the project size, if the project is large, up to 100 people, I will use Nexus and if more than 100, we follow Nexus+. This can be suitable to scale SCRUM."

R14 (Chief Knowledge Engineer): "If they are working on a single program of work, then you got to add in some project management, you got to add in work value management, you got to add cross-team collaboration, you got to add in probably some rigor tooling. Your governance processes might have to be a little bit more when you do a robust work as it will be a little bit more extreme. So, DAD, LeSS, SAFe and Spotify could guide you when the project is large."

2) Project criticality: Critical projects are those projects that might cause essential loose of money or human lives [5]. An understanding of the criticality of the project can help in determining differences in the results of applying different Agile methods. Most of the respondents mentioned that XP method and TDD Agile modeling, Lean Startup, DAD and SAFe are the main methods to be used in the development of critical projects:

R23: "For critical projects, you must select the process that brings the most amount of feasibility and predictability. In my opinion, the one that I've had the most successful outcomes from is from the XP point of view." Agile Coach

R5 (Project Manager): "XP practices should be adopted for critical projects and you should apply TDD."

Other respondents suggested other methods to be used for critical projects, such as Agile modeling, Lean Startup, DAD and SAFe.

R16 (Senior Consulting Partner): "If you are doing financial processing system, which is very critical, then sequence diagrams and other modeling under Agile modeling approach could be appropriate but again, if the team does not have sequence modelling skills, then this would be a bad choice."

R21 (Project Manager): "If the project is really critical, then you need to get this out of the door by UX. You need to talk about feature prioritization and what is MVP from that point of view, So, Lean Startup practices assist you in understanding how to solve critical issues."

R5 (Project Manager): "Methods like SAFe or DAD, does lead the way as to how to reduce the amount of complexity and have more flexibility within the organization and that includes reducing the criticality and the amount of dependency."

3) Project decomposability: Agile methods assist teams respond to unpredictability through incremental, iterative work cadences and empirical feedback. However, some projects are difficult to be implemented in an iterative or incremental manner. Examples of such projects could be airplane, elevator, airbus, mobile and car. They are difficult to be decomposed but they could be implemented successfully when the right approach is selected. There is a need for initial modelling, initial planning, testing regularly and milestone instead of sprints. So, Kanban, Lean Development, Lean Startup and DAD are more appropriate if the product is difficult to be decomposed:

R16 (Senior Consulting Partner): "The major components of the A380 airbus were delivered in parts even it was so difficult to decompose it. So, once again for this kind of project, I get back to initial modelling, initial planning and

testing all the way through, which means a combination of methods is needed. However, DAD was capable of doing this and it could assist the team to release the project at a single time but build the project in pieces."

R21 (Project Manager): "If you can decompose it into sprints, you can use SCRUM, if you cannot decompose, then you can use Kanban, which allows you to use milestone."

R18 (Chief Information Officer): "Look at how they develop the rockets or Samsung S5, S6 and S7. They should make sure how the old one can still plug into the new component. So, in this case, practices of Lean approaches such as, MVP would help in understanding how such a product could be decomposed considering the customers' need."

4) Project maturity: Different product maturity at different stages of the development should be considered when selecting Agile methods. The analysis revealed that product maturity could be divided into four stages namely, legacy product, new product, development stage and maintenance stage.

If the product is a legacy product, which contains legacy code, then the appropriate methods to be used is XP method. In addition, TDD is difficult to be used in this case:

R3 (Delivery Manager): "If the team is coding legacy code, TDD will be difficult for them because the design of the code is such that some codes are really written in a way that is very difficult to test. So, TDD will always be difficult to be used for a legacy product."

R9 (Agile Adoption Change Leader): "For legacy code, XP practices such as pairing and refactoring are good at ensuring you don't create any more technical debt."

The second stage of project maturity is when the product is something new in which case, we have to start from scratch. Lean startup, TDD and DSDM are the most appropriate Agile methods for this:

R13 (Project Manager): "If I am implementing a new project, I can use DSDM but when it goes for maintenance project I will follow Kanban."

R17 (Senior Agile Developer): "We have to use TDD when there are new projects that we have no idea about it."

R16 (Senior Consulting Partner): "Typically, the Lean Startup method or we call it the exploratory life cycle, is used when you are dealing with new product development."

When the product is in the development or prototype stage, then SCRUM and/or XP would be a better choice:

R3 (Delivery Manager): "Well, as we are moving out with the prototype stage I will involve SCRUM and some XP practices."

Finally if the product is in the maintenance stage then Lean development, DevOps and Kanban methods are the appropriate methods to be used. In other words, for maintenance and support products, adopting Kanban or DevOps has higher success rates compared to SCRUM.

R11 (Product and Management Consultant): "For support and operational product blindly, a Kanban is suitable but for maintenance, Kanban & DevOps are both suitable."

In addition, methods such as Adaptive Software Development (ASD) and Lean development are also appropriate:

R3 (Delivery Manager): "If the customer provides clear features, and refuses to see the step by step development as the end is known through the use of product, this is where the maturity of the product comes. In this case, I will probably go with Lean Development or Kanban, because at the end of it, I'll show you the product, instead of showing you something that is still incomplete."

R13 (Project Manager): "I will follow ASD or Kanban as Kanban flow would help us in mentoring the tasks."

B. Development Team Proficiency

Successful Agile methods can be achieved through team proficiency. For instance, team communication skills are very important when selecting Agile methods. Such proficiency may differ from one firm to the next, so this factor has to be considered when selecting a specific Agile method. It is crucial for project managers to confirm the proficiency of the team and on this basis, they can follow-up on what to do and which Agile methods to select. The description of the factors that have been highlighted under the category of team proficiency are provided in this sub-section.

1) Team communication skills: The success of adopting Agile methods requires extensive communication skills. The analysis revealed that the team communications skills affect the selection of Agile methods. If the team is co-located and their communication skills are poor, then there is a need for improvement. Respondents contended that XP and SCRUM are very suitable to improve the communication skills among the team:

R23 (Agile Coach): "I would try to have an assessment of problem solving among members, how to go about their work, how they communicate and collaborate among themselves and try to suggest different ways that help them to learn, and in this regard, SCRUM and XP practices will build communication. Pair programming, retrospectives are examples of how to help your team communicate."

R4 (Chief Executive Officer): "SCRUM forces us to communicate in different stages of the project."

However, if the team members are distributed or if there are solo developers, then the communication between them will be less. In this case tailored Agile methods such as DAD is needed. Moreover, DevOps and Kanban methods are suitable when there is distribution:

R16 (Senior Consultant Partner): "You have to tailor your approach to reflect geographical distribution which affect the communication between developers, the way you communicate within the team, whether the team changed, and you have to get in people around and more often. You probably have more sophisticated planning and documentation. So, the way you

work in that environment is different than if you work in a co-located environment but you can still be Agile by planning a bit in advance, this is how DAD works."

R18 (Chief Information Officer): "Kanban might have the steps of where you can conceive a story and someone picks up that story, there is nothing in parallel, it is all in sequence. So, we can control the work in progress (WIP). So, that is different approach for the same problem and it will be conceivable that it is easier to support a developer in one location and QA in another location in different time zones, if at least your developer finishes the work and then called up the QAs in different time zone "Hey I have just finished story A, B and C", can you comment testing. Then possible answer of the QAs to the PO at the end of the day would be, "Hey I just finish testing these, check them for acceptance". It is conceivable that Kanban may work better in this progress rather than say SCRUM. So, Kanban is better for a distributed team."

R23 (Agile Coach): "In DevOps, Solo developer builds, then deploys to package the functions, which have dependencies and then transfers them to the server. So, it really helps those solo developers to communicate with others without even knowing that but normally solo developers are really experts in continuous integration and delivery."

2) Team domain knowledge: Excellent team domain knowledge has been found to contribute to the success of Agile methods' use [13]. Team's domain knowledge is considered as an important factor in the selection of Agile methods [14]. The analysis of this empirical study revealed that team's domain knowledge influence the selection of Agile methods, if the team does not really understand the project to be built and how it will match the customers' need, then Lean Startup would be the optimal method to be selected:

R17 (Senior Agile Developer): "We have implemented a new project for the deaf and we did not know the details or the information about the project as it was not clearly defined … we found that Lean Startup to be the most appropriate method because it allowed us to examine the output, it helped us to organize things in a good manner."

In addition, it was found that DAD, XP and DSDM would be appropriate when the domain knowledge is low:

R5 (Project Manager): "DAD, Lean Startup and DSDM emphasize on understanding the customers well before you start the projects, especially when the team does not understand the customers' needs."

R19 (Agile Trainer & Consultant): "If there is no domain knowledge, I will focus more on applying pair programming and I will bring the people who requested the business to be available with us all the time. So, XP practices are very important in this case."

However, if the team domain knowledge is high or they have a good idea of the product backlog, then the team could move toward Lean development, Kanban and DevOps.

R3 (Delivery Manager): "If the team is consistent and knows the domain properly, indicating good domain knowledge, I will go toward Lean Development or Kanban, then we can just focus on improving the flow."

R1 Project Manager: "The knowledge of domain for the developers must be very high when selecting DevOps."

3) Team competency: Competency in this empirical study refers to team maturity (whether a team has real-world experience in using a specific Agile method or has built similar systems in the past using a specific Agile method) and the technical skills of the team to be able to adopt a specific Agile method. Both factors are discussed as follows:

a) Team Maturity: Different teams will need different things at different points of time, based on their maturity in using Agile methods. Therefore, selecting the method can be aligned with what the development team are familiar with and how matured are they in using Agile methods. So, most of the organizations select an Agile methods including many practices based on the team maturity. If the team in new to Agile methods, then the most appropriate Agile methods are the prescriptive methods and SCRUM is an optimum example of that:

R15 (Director of Development Management): "SCRUM is suitable for this group since they are beginners in using Agile methods."

In addition, it was found that DSDM is also appropriate for new Agile adopters since it is prescriptive as well. Additionally, Lean Startup can be used when the team is not matured in using Agile methods:

R6 (Agile Consultant): "We consider the team capability when selecting a specific Agile method. Some of the teams are not familiar with Agile methods. So, if the team capability is low, then we will give them some leverage on how to use Agile method by using either SCRUM, DSDM or Lean Startup."

However, when the team is mature in using prescriptive Agile methods, they should start thinking of adopting advanced Agile methods such as DevOps, Kanban, Lean Development, FDD. The latter methods require the team to be mature and have high competency in using Agile methods:

R1 (Project Manager): "If the team is not matured, then DevOps is not a choice."

R23 (Agile Coach): "Kanban is a cancer when the team is not an expert in using Agile methods, so we go back to SCRUM."

R6 (Agile Consultant): "If the team has high capability, they are competent and experienced in using Agile methods. Then we can choose Lean development or FDD."

b) Team technical skills: Technical skills of the team are an important factor, which affect the selection of Agile methods. In many organizations low skilled people exist who cannot use specific methods or they lack the technical skills, which allow them to adopt specific methods. Methods such as TDD and XP require high technical skills in order to be selected since most of their practices are engineering practices:

R20 (Team Leader and Development Manager): "The technical skills should be high when adopting XP, as new programmers will never be able to use TDD as they will not think of testing before coding. Juniors will always face difficulties when adopting TDD."

In addition, it was found that DevOps require the team to have high technical skills to be able integrate, deliver automatically, test, monitor and deploy small chunks of software together.

R17 (Senior Agile Developer): "To adopt DevOps, the technical skills should be very good especially when considering the tools that should be used by the team. Many developers do not know how to use the DevOps, particularly when it comes to automation of the software delivery."

Adding together, Agile modeling and FDD require the team to be technically skilled, especially the modeling and the architecture skills.

R5 (Director of the Agile Organisation): "The technical architecture skills are highly needed when Agile modeling or FDD is selected."

C. Customer Involvement

It is important for customers to be actively involved in Agile methods procedure as without this involvement, then the team should opt for the Agile methods that are appropriate in understanding the customer's needs in advance. For instance, Adaptive Software Development (ASD) method emphasized on using joint application development session to increase customer involvement [15]. Hence, the customer should be encouraged and convinced of the significance of his involvement. Under this category, customer collaboration, customer domain knowledge and customer commitment are the main factors affecting the selection of Agile methods.

1) Customer collaboration: Customer collaboration in traditional methods such as waterfall is achieved by providing the requirements in the beginning and feedback towards the end, generally there is no regular interactions and collaborations between the customer and the development team. However, this is not the case when using Agile methods where the customer should interact and collaborate well with the team. Fortunately, with the increased number of Agile methods low and high customer collaboration can be handled. For instance, the analysis of this empirical study revealed that XP, SCRUM and Kanban will never be suitable when the customer is not collaborating well with the development team:

R15 (Director of Development Management): "If there is no customer collaboration, your project will fail for sure. SCRUM without customer collaboration will fail. Kanban is the same."

R12 (Principal Consultant): "XP practices might not help at all when the customer is not collaborating. Even, on-site customer will not help if the customer is not collaborating."

However, other Agile methods are appropriate even when customer is not collaborating well and this includes Adaptive Software Development (ASD), Agile modeling and Lean Startup. Both methods assist in understanding the customers well and being able to find the appropriate way to get them involved and/or understand their requirements in advance.

R16 (Senior Consulting Partner): "Agile modeling techniques and regular demos would help in understanding the customer and helping them to collaborate well. So, these are the main practices that would help when the customer is not collaborating as expected."

R19 (Agile Trainer & Consultant): "If the customer is not collaborative or not committed, then either the project will fail or I need to follow Lean Startup to be able to understand their needs effectively."

R12 (Principal Consultant): "Adaptive software development force the customer to get involved by developing simple prototypes during regular JAD sessions."

In addition, scaled Agile methods such as, DAD and SAFe are also appropriate when the customer is not collaborative as expected. For instance, DAD and SAFe encourage the team to understand the customer needs in advance.

R7 (Project Manager): "Many customers are not free or are careless to check each sprint; they just agree on what we provide for them, but at the end of the project we will get a lot of complains. In this case, we should use DAD or SAFe, both help in envisioning the needs of the customer in advance."

2) Customer domain knowledge: The customer or customer representative should have the ability to regularly provide the project requirements when using Agile methods. The analysis on or empirical study revealed that customer knowledge of their needs is an important factor, which affects the selection of Agile methods. Lean Startup, DAD, SAFe and FDD methods were found to be helpful when the customer domain knowledge is low. For instance, SAFe emphasizes on using UX when the customer domain knowledge is low:

R12 (Principal Consultant): "UX might be the best when the customer domain knowledge is low because this gets them into testing stage. You are really looking at it from the customer experience point of view. FDD might be also appropriate if you are able to select different customers looking for different things."

R16 (Senior Consulting Partner): "DAD is appropriate when there is a need for initial planning to solve dependencies issue and initial requirements gathering, especially when the customer does not know what he exactly needs. This calls for more architecture for the same issue including the team's understanding of what exactly to implement. Lean Startup is also appropriate"

R5 (Project Manager): "Also UX is another discipline technique. So, they do customer development, customer interview, prototyping and basically it fits into Agile. SAFe emphasizes on adopting UX. It complements Agile of the incremental development of product or service and through demos, rapid and frequent feedback from the customer can be obtained for better understanding and definition of the problem."

Other methods such as XP and SCRUM, require the customer to have high domain knowledge to be active during the development:

R15 (Director of Development Management): "If the customers have high knowledge of what they want, they understand what they need exactly, then I will use XP method."

R2 (VP of Engineering and Operation): "If the customer knowledge of domain is high, then SCRUM can be the most suitable one."

3) Customer commitment: Customer commitment refers to the customer's active, motivated and responsible character in providing adequate requirements and testing the delivered sprints. However, the analysis of our empirical data revealed that customer commitment may differ from one project to another, as some might be busy and they might not be able to be involved as expected during the development processes. Based on the interview it was found that DAD method could be appropriate when the customer commitment is low as DAD assists in defining roles and responsibilities for the customer that can be structured forward. Kanban and SCRUM will not work well and there is a need to apply a bit of up-front planning at the planning stage:

R19 (Agile Trainer & Consultant): "When there is no customer commitment, Kanban and SCRUM will not work well, and you need to apply a bit of up-front planning at the planning stage. You could follow DAD guidance in this case"

It was also found that Lean Startup is appropriate when the customer commitment is low. Lean Startup allows Agile team to understand the requirements and the needs in advance:

R19 (Agile Trainer & Consultant): "If the customer is not collaborative or not committed, then either the project will fail or you need to follow Lean Startup to be able to understand their needs properly."

SCRUM method will be suitable when the customers are highly committed, especially in following the sprint planning. For instance, if it is two weeks sprint, then the customer should be committed to verify the work every two weeks.

R21 (Project Manager): "Having SCRUM is a bad idea when the customer is not committed because staff has to be sent out and this particular sprint will deliver multiple times (1, 2, 3) without feedback. Then you'll move on to 4, 5, 6 assuming that everything is going to be okay, but then you get stuck. It really depends on the nature of how committed your clients/stakeholders are when they get involved."

D. Organizational Culture (Type of Organization)

Generally, Agile methods assume the team members are working in a collaborative manner rather than in a hierarchical one. Nevertheless, this empirical analysis revealed that some organizations have a hierarchical structure but are eager to be Agile. Therefore, in order to use Agile methods, the organization has to adapt its culture, and for this, Kanban and SAFe methods could lend a hand as they allow top management to monitor the progress of the development:

R10 (Senior Consultant): "Do you know an organization which is extremely hierarchical but still really agile? It is called TOYOTA. So, Kanban and Lean development methods could be adopted when there is a need to control the process."

R12 (Principal Consultant): "If you are truly hierarchical, then I think you have to go with something that is well planned ahead. Because the hierarchy always demands what the team is going to build and when it is going to be ready. They might say "I need this now" or "I need this commitment" and thus, things like Kanban and SAFe can work as they have predictable sketch along the way."

In addition, it was also found that SCRUM method would help when the organization is at the transition stage "immature team" but the development team members themselves should be collaborative.

R6 (Agile Consultant): "Even with hierarchical culture, we can choose SCRUM method if the team members themselves collaborate with each other."

R9 (Change Leader): "If the organization is already agile, I would opt for Kanban rather than SCRUM, particularly when the culture is hierarchical." Agile Adoption

Finally, DSDM would also assist the management to control the work.

R8 (Director of the Agile Organization): "I do not think DSDM improve the quality when compared to TDD and XP but for some organizations, which are highly bureaucratic, DSDM might be helpful."

E. Project Constraints

The development team can employ any appropriate method to their preferences, but with strict constraints, depending on the context. For instance, some organizations are faced with the challenge of dealing with quality products, while others have issues with time to market, scope variability and project costs. In addition, the analysis of the empirical result revealed that requirement volatility and cost of change are other challenges that organizations face. These are the primary constraints that have to be kept under consideration during Agile methods selection. In other words, the team has to determine the most suitable method that is consistent with the constraints. The project constraints are described in detail on the basis of the feedback obtained from the respondents in the next paragraphs by category.

1) Time: Different organizations are faced with different challenges, with one of the main challenges being time to market, which affects the selection of Agile methods in two ways. First of all, the speed of the delivery and in this regard, DevOps was found to focus on this purpose:

R1 (Project Manager): "We want to have quick and fast delivery, so we adopt DevOps."

In addition, it was also found that XP and Kanban also focus on delivering the project fast. XP focuses on coding and continuous integration and Kanban focuses on managing the flows instead of managing the iterations, which makes the progress faster:

R15 (Director of Development Management): "If the team has good technical skills and experience in using XP practices, they could use Kanban to manage the work, which will make the process faster, especially if the customer provides regular and daily feedback."

R17 (Senior Agile Developer): "we will immediately use XP to develop the project fast especially if we have a team who has good programming skills, loves coding and has skills of continuous integration."

Sometimes, the customer might request a fixed schedule for each sprint of the project so the sprints delivery should be at a specific date, then the methods are called for which enables this and they are SCRUM and DAD:

R11 (Product and Management Consultant): "With time-bound scope, I will go with SCRUM, otherwise I will go with Kanban."

R12 (Principal Consultant): "If you got really strong contractual requirements, you may have something that needs delivery of functions at each step of the way or penalty payment, in which case you need to have something that is more disciplined in order to be able to manage it more closely. In this case, DAD would be a very good choice."

2) Quality: Agile methods in general, focus on increasing the quality of the products. Some Agile methods and Agile methods' practices are required when the challenges are to deal with quality of products to effectively and efficiently accelerate activities [16, 17]. XP methods and TDD were found to be the most appropriate methods to increase the quality and deal with such challenges:

R8 (Director of the Agile Organization): "In almost all cases, to get high quality product I'd recommend *also* to adopt the XP practices."

R20 (Team Leader and Development Manager): "The adoption of TDD would help a lot in improving the quality."

In addition to XP and TDD, it was also found that DAD and SCRUM retrospective increase the quality. DAD contains a bit of architecture visioning and upfront planning and SCRUM retrospective helps the team to solve the quality issues:

R16 (Senior Consulting Partner): "Also, I might opt for upfront architecture envisioning for better quality and in this case we could use DAD or Agile modeling."

R5 (Project Manager): "SCRUM Retrospective improves the quality, especially when the team focuses on the items that should be delivered with a hundred percent quality."

3) Scope variability: The scope of an Agile project is not defined by detailed requirements but by the high level requirements such as, user stories. Based on the analysis, it was found that scope variability affects the selection of Agile methods in that if the scope variability is high and there are difficulties in batching the requirements into two weeks' time, in which case, Kanban and Lean development are the appropriate methods to be used:

R10 (Senior Consultant): "The more the scope is unpredictable, the less lead time it can endure. Kaizen's premise is fail fast, find problems and fix them and both apply Kanban and Lean in this case, which will decrease the cost of implementation and help the team to limit the work in process and focus on one thing during the implementation."

Moreover, SCRUM method will not be suitable when the scope variability is high, especially if the predictability of the scope is not stable:

R11 (Product and Management Consultant): "Understanding the context and the problem calls for scope predictability in a stable environment, then SCRUM would be a good choice. This can be done in 2-4 weeks' time. You need to deliver and freeze, then employ SCRUM but if scope predictability is a dynamic environment, then go with Kanban"

4) Requirements variability: Requirements volatility means that your requirements are changing dramatically on daily basis or sometimes on hourly basis. So, if the requirements volatility is high, then Kanban is the most appropriate method to be selected. Therefore, it depends on whether the requirements of the customer are stable or not:

R14 (Chief Knowledge Engineer)"If you are working with highly volatile requirement, then you need an Agile method, which can help you deal with that – in other words, you need iterative development, very short iterations, user stories and elaborated just in time. So, Kanban is suitable for that."

R21 (Project Manager): "Kanban could be very good if the management of the banks keep adding new requirements in the middle of each sprint."

In addition, DAD could be used to have a clear picture of the final product in advance, so if there is possibility of requirement changes, it will be clear before starting the implementation of the product. Also Lean methods could be used to allow a failing team to get early feedback:

R7 (Project Manager): "If the scope is not clear but the requirements are stable and can be batched, then we can adopt SCRUM but if the requirements are not stable and there can be daily changes, then something, which allows upfront planning to understand the requirements can be adopted, in which case, DAD can guide on how to understand the big picture of the project in advance."

SCRUM is suitable when the requirements are stable or at least the changes are not on a daily basis. So, it can be used when the requirements keep on changing but if the requirements volatility is high, then it's better to use Kanban:

R6 (Agile Consultant): "SCRUM can be used for brand new projects but if the requirements are volatile and changing rapidly then it's better not to use SCRUM for brand new projects."

5) Cost/Value/ROI: In general, most Agile methods focus on reducing the cost of software development. However, there are some methods which emphasize on being cost-effective. So, by adopting that specific Agile method, the development cost will be decreased. This can be achieved by decreasing

any extra features, delays and defects, which decreases the cost of the implementation. Some methods help in providing what is being asked by the customer or limiting the work to deliver the right requirements only without providing extra things, which might not provide value for the customer. DevOps/Continuous delivery and XP methods were found appropriate in decreasing the project cost as supported by different Agilists as follows:

R14 (Chief Knowledge Engineer): "I personally take and advice my team to adopt is the XP philosophy. Anything below that just results in a technical debt and long term cost."

R17 (Senior Agile Developer): "For projects, which have small budgets, the best method to be used is DevOps as it helps in delivering the project faster."

In addition, Kanban, Lean Startup and Lean development were found to be appropriate in decreasing the cost. They focus on developing the right requirements, which return investment in a timely manner. In addition, they focus on eliminating waste by not performing unnecessary things. For instance, Kanban helps the team to focus on small pieces of work to be able to control the flow, so unnecessary ceremonies will be prevented:

R8 (Director of the Agile Organization): "When there is a cost constraint, I might consider having a preference for Lean or Kanban type approach because it allows us to focus on eliminating waste."

V. Discussion

Based on the results above, Agile methods selection model in Fig. 1 illustrates the factors that have been found to affect the selection of an Agile methods. The Agile methods, whose efficacy is affected by these factors are shown in the center box in Fig. 1. Each factor comprises different values that can be used in the selection of different Agile methods.

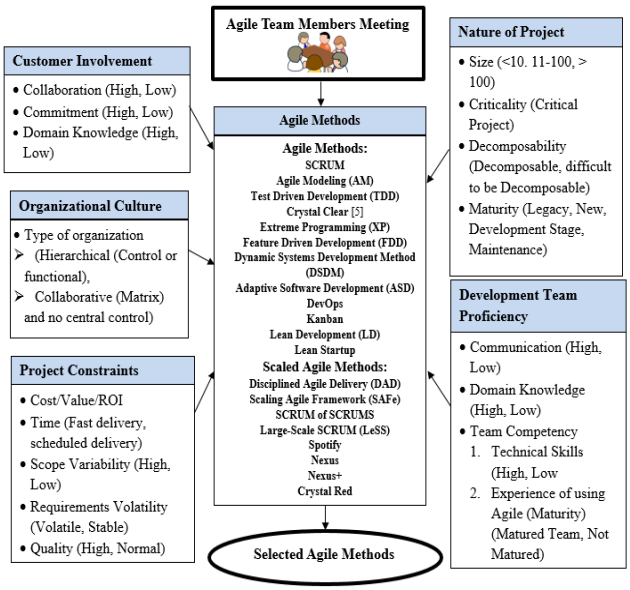

Fig. 1. Agile Methods Selection Model.

The analysis grouped the factors into five categories. By considering the degree to which each of the identified factors is important to the project, Agile team members should conduct a meeting to discuss the targeted projects to be implemented and the factors, which affect the selection of the methods. Team meeting in the selection of Agile methods was supported by different respondents to select the appropriate Agile methods. The findings would contribute in the selection of the appropriate Agile methods for different development projects in different organizations, and this leads to the delivery of high quality software with reasonable cost and efficient time usage.

VI. Conclusion

Agile methods selection should be considered at each and every organization while keeping different teams and projects under consideration. Selecting the right Agile methods has a pertinent influence on the success of implementing any project. This research presented various recommendations about the situations in which an Agile methods can be suitable. Individual interviews were used to explore the different practices that Agile teams normally follow to select the appropriate Agile methods for different projects and/or different teams at different organizations. The results from the data collection were imported into NVivo, a qualitative data analysis software package. Several factors were identified including how they could be used in selecting Agile methods based on grounded theory analysis. The result indicates how each factor could be used in the selection and this is the key to answering the main research question of this study. Further work can be undertaken to investigate the appropriate Agile methods and Agile methods practices for requirements reuse, which is an important topic. In addition, other factors and new Agile methods may emerge for the development of specific projects [18]. So, selecting the appropriate Agile methods can be investigated again.

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A Group Cooperative Coding Model for Dense Wireless Networks

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***Abstract*—Generally, node groups in dense wireless networks (WNs) often pose the problem of communication between the central node and the rest of the nodes in a group. Adaptive Network Coded Cooperation (ANCC) for wireless central node networks adapts precisely to an extensive and dense WN, at this level the random linear network coding (RLNC) scheme with Low-Density Parity-Check (LDPC) are used as the essential ANCC evolution. This paper suggests two phases effective technique then studies the influence of the randomly chosen number of coded symbols which are correctly received in the second phase on bit error rate (BER). The proposed technique also focuses on the role of dispersion impact related to the LDPC code generating matrix. The results of the simulation allow selecting the best compromise for the best BER.**

***Keywords*—Dense Wireless networks; Bit Error Rate (BER); Low-Density Parity-Check (LDPC) codes**

I. INTRODUCTION

The present paper analyzes a network coding scheme for dense wireless networks as in the case of the wireless sensor networks (WSNs) especially as regards the energy efficiency a cording to [1], [2], [3] or improvement planning at Bit-error rate (BER) as in [4]. This type of network consists of a large set of nodes that cover a relatively small area and whose nodes collect information from the environment and send it periodically to one or more common destinations. In this type of networks it cannot be guaranteed that all nodes have a direct connection with the destination node, so it is very common for the rest of the nodes to collaborate correctly so that the original information reaches its destination by means of retransmissions as in [5] . The use of isotropic antennas allows the nodes to establish neighborhoods, since they are in the coverage radius of other nodes.

The Network Coding (NC) scheme, which has been used as base of the development, is the ANCC (Adaptive Network Coded Cooperation) [6], [7], that adapts precisely to the extensive and the dense WSN and also to the internet of things (IoT) networks [8].

Network Coding [9] is a special case of Cooperative Communication where the topology of a network is exploited to increase its performance [10] and according to [11] it can also improve end to end delays. The network's own nodes are those that encode the transmission, allowing parts of the message that is transmitted to its destination to go in different ways, thus increasing the capacity of the system in multicast networks [9], [12]. Another possibility is that the different ways to reduce the number of errors in transmission by sending several copies of the same messages by different paths to their destination [13].

Employing wireless NC [14], [15] in user cooperation, (ANCC) [16[, [17] completely exploits time division techniques (TDMA) for channel code in distributed destinations, which is composed of two phases: sending phase and resending phase. In the sending phase, each node sends its own original data while the others keep silent and decode the packets which have been arrived with the appropriate level. In the resending phase, the central node, randomly chooses several packets to form the resending packets.

In this scheme, it is proposed to combine the network in the form of a graph (network on graph), describing the instant topology of a network, with the codes based on graphs (codes on graph) and which can be adapted to the ad-hoc nature of a wireless network, such as LDPC codes.

The LDPC codes are a category of error correction codes proposed in 1963 [18] by Robert Gallager .These codes are characterized by having a little dense generating matrix G, that is, a binary generating matrix containing a high number of zeros and therefore a low number of ones. Gallager defined the LDPC codes as a CLDPC code (n, j, k) where n is the length of the code words (in English codeword), j the number of ones in per column and k the number of ones per row.

ANCC flexibly produces a selection of LDPC codes [19], [20] in a distributed aspect at the destination. In these codes, all the code words that can be formed from the same generating matrix they find, like in [21], each other at the same distance from each other.

Initially, the LDPC codes were not very successful and fell into oblivion because they required more computing power for their decoding and the capacity of the computers of the time was quite limited. Only authors in [22] such as Tanner have attempted to obtain a valid implementation of Gallager codes. The appearance of turbo-codes in 1993 [23] and advances in computability led the scientific community to rediscover these codes in the mid-1990s [24], [25]. The RNLC and LDPC are used in [26] to more accurately measure the standing wave ratio of an antenna system in a dense WN.

The most typically exploited algorithm for decoding LDPC codes is the Sum-Product algorithm (SPA) [25], or belief

propagation algorithm. SPA is the most basic form to implement the iterative decoding of LDPC codes. This algorithm is an iterative algorithm that estimates the posterior probability of the symbols from the parity check matrix, the received symbols and the likelihoods of the symbols passing through the channel. According to [10], it should be mentioned here that the increase of iterations number has no influence on the system performance.

The main contribution in this paper is the development of a technique using LDPC codes and RLNC in ANCC for reducing the BER value in dense WN, it is distinguishable to analyze how the value of parameter β influences the results and what values of this parameter are valid for the nodes group in dense network

The remainder of this paper is structured as follows. The Section II summarizes the mathematical principles of LDPC codes. Section III presents a system model and the description of the proposed technique. Section IV presents simulation results. Section V closes this paper with a conclusion by determining the subject of the future work.

II. Mathematical Principles of LDPC

The coding of the LDPC codes does not differ from the coding of any block code. Below we summarize the vectors and matrices that intervene in the coding [27] of our approach

1) Vector of information u: It is the vector composed of the N bits of information, each one of them comes from each of the nodes that transmit the information:

$$u = [u_1, u_2, ..., u_N] \tag{1}$$

2) Generator matrix G: is a matrix of size $N \times 2N$ that is used to generate the coded words. This matrix is defined by the identity matrix I_N and the matrix P, which is responsible for generating the parity bits presented in the coded words. The way to obtain the matrix P depends on the parity equations that we want to use.

$$G = [I_N P] \tag{2}$$

3) Vector of coded information (c) is the vector that results from coding the information vector u with the generating matrix G.It has length $2N$ so that the first N bits correspond to the original information bits and the last N bits correspond to linear combinations (defined by the matrix P) of the information bits.

$$c = \mu G = [c_1, c_2, ..., c_m, c_{m+1}, c_{m+2}, ..., c_{2m}] \tag{3}$$

where

$$[c_1, c_2, ..., c_m] = [\mu_1, \mu_2, ..., \mu_m] \tag{4}$$

and

$$[c_{m+1}, c_{m+2}, ..., c_{2m}] = [\mu_1, \mu_2, ..., \mu_m]P \tag{5}$$

4) Parity check matrix H is matrix designed for the systematic code generated by G that will have dimensions *Nx2N*. The H matrix which is used for simulation is constructed according to orthogonality of the matrix G and the matrix H row vectors multiplication. So that:

$$H = [P^T I_N] \tag{6}$$

$$G.H^T = 0 \tag{7}$$

Where P^T and H^T are the transposed matrices of P and H respectively.

III. System Model and the Description of the Proposed Technique

A. System Model

Assume a monitoring system model where nodes are connected either by wireless as illustrated in Fig. 1. The purpose of this monitoring system model is to provide data, which accurately reflects the critical conditions of renewable energy.

Consider a network consists of m nodes (monitoring labeled $n_1, n_2, n_3, ..., n_m$, and a central node as topology shown in Fig. 1. We assume that each node transmit one native symbol in this phase and we model the network by a directed graph (N, L) , where N is the set of nodes $\{u_1, u_2, u_3, ..., u_m\} \in N$ and L is the set of the wireless directed links. The central node, at the center of the figure, wishes exchange symbols denoted $s_1, s_2, s_3, ..., s_m$ coming from all nodes of the network. Suppose now that the nodes are in the communication range.

Fig. 1 represent a directed graph consisted of set m nodes, each node is represented by a circle, with the name of the node inside. The starting node is named by n_1.

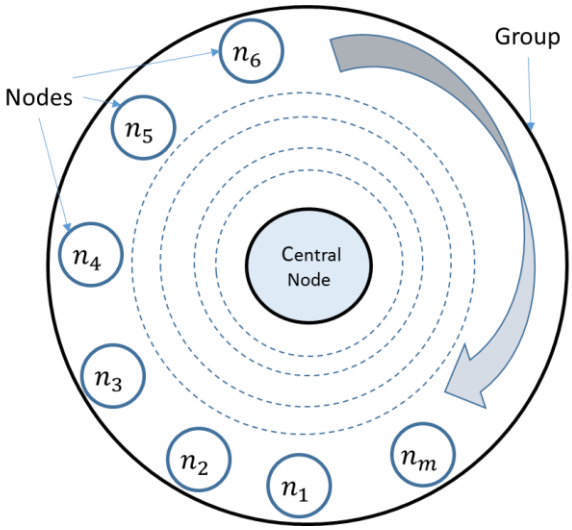

Fig. 1. A Group of ANCC Scheme that uses Network Coding with LDPC Codes.

B. Scenario Description

1) Sending phase: Fig. 1 shows the transmission of nodes $n_1, n_2, n_3, ..., n_m$. The node n_1 transmits its symbol and both the central node and the rest of the nodes remain silent and listen to the symbol that node n_1 has transmitted. The rest of the nodes analyze the received symbol and verify if it is considered correctly received or not. If the node considers that it has been properly received , it proceeds to store the symbol sent by node n_1 .Otherwise, the symbols must be discarded. In addition, the central node can also stores the symbol s_1 sent by node n_1 .

After the transmission of the node n_1 , the node n_2 begins the transmission of a symbol s_2 .As explained for node n_1 , the node n_2 transmits its symbol, while the rest of the nodes of the network listen to the channel and store the symbol s_2 if they estimate that it has been received correctly.

In this case, the nodes $n_1, \cancel{n_2}, n_3, ..., n_m$ (except node n_2) store the symbol s_2 . The central node also stores the symbol s_2 . These steps are repeated for the transmission of the symbols of the rest of the network nodes. Finally, the central node has received all symbols $s_1, s_2, s_3, ..., s_m$. Consequently, the information vector is composed of the symbols that have transmitted all the nodes $u = (s_1, s_2, s_3, ..., s_m)$.

Once all the nodes in the network have transmitted their symbols, the resending phase begins which starts with choosing to combine the symbols received correctly. The idea of embedding the coefficients used in the linear combination, in the packet header, was introduced in [28] by the work of Chou et al. As well as the idea of local opportunistic coding to present a practical implementation of a network coded system was used in [29] for unicast.

Therefore, each node chooses the β symbols that have received perfectly in the previous phase. When one of the nodes has fewer than β nodes, it would transmit only the nodes that have correctly received, by producing a generator matrix G with a number below the β ones in the corresponding column.

The behavior of the resending phase is quite similar to that of the nodes in the sending phase. Each node emits the elaborated symbol (under another form: encoded symbol) while the rest of the symbols remain silent.

The main difference between the two phases is that in this second phase, it is no longer necessary for the nodes to listen to the symbols transmitted by the rest of the nodes. In this second phase only the central node must listen and store the symbols.

2) Resending phase: The process of the second phase is as follows:

First, all the nodes in the network prepare the symbol they are going to send in the resending phase. Subsequently, node n_1 sends the corresponding symbol $\sum_{i=1}^{\beta} \oplus s_i \quad , \beta \leq m$ together with the headers needed to decode it in the central node where $\oplus$ represents the binary sum, with what the expression $\sum_{i=1}^{\beta} \oplus s_i$ represents the binary sum of the symbols $s_1 \oplus, ... \oplus s_\beta = s^c$.

The central node receives and stores the received information. These steps are repeated for nodes $n_1, n_2, n_3, ... and\ n_m$, which transmit their corresponding symbols $s_1, s_2, s_3, ..., s_m$ respectively.

Finally, the central node has received all the data corresponding to both phases. Thus, after these two phases, and from (4) and (5) we have that the encoded information vector c is:

$$c = [s_1, s_2, s_3, ..., s_n, m \times \sum_{i=1}^{\beta} \oplus s_i] \tag{8}$$

From the previous data the central node can build the generator matrix G . This requires the matrix that expresses the equations parity P . This matrix P is built from the information of the resending phase. The element $s^c{}_{i.j}$ (coded symbol) has a value 1, if the node corresponding to row i participates in the binary sum of the response what issues the node that corresponds to column i , it is 0 if not involved. So the resulting matrix P is:

$$P = \begin{bmatrix} {}^{n_1} & {}^{n_2} & & {}^{n_m} \\ s^c{}_{1.1} & s^c{}_{1.2} & \cdots & s^c{}_{1.m} \}n_1 \\ s^c{}_{2.1} & s^c{}_{2.2} & \cdots & s^c{}_{2.m} \}n_2 \\ \vdots & \vdots & \ddots & \vdots \\ s^c{}_{m.1} & s^c{}_{m.2} & \cdots & s^c{}_{m.m} \}n_m \end{bmatrix}$$

where on the top, it has been tagged the node which correspond to each column and the on right side, the node corresponds to each row.

According to (2) and the matrix P , we can build the matrix G responsible for generating this code, which is as follows:

$$G=\begin{bmatrix} \overset{n_1}{s_{1.1}=1} & \overset{n_2}{s_{1.2}=0} & \cdots & \overset{n_m}{s_{1.m}=0} & \overset{n_1}{s^c_{1.m+1}} & \overbrace{s^c_{1.m+2}}^{n_2} & \cdots & \overbrace{s^c_{1.m+m}}^{n_m}\}n_1 \\ s_{2.1}=0 & s_{2.2}=1 & \cdots & s_{2.m}=0 & s^c_{2.m+1} & s^c_{2.m+2} & \cdots & s^c_{2.m+2}\}n_2 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots \\ s_{m.1}=0 & s_{m.2}=0 & \cdots & s_{m.m}=1 & s^c_{m.m+1} & s^c_{m.m+2} & \cdots & s^c_{m.m+m}\}n_m \end{bmatrix}$$

which leads to the next matrix:

$$G=\begin{bmatrix} 1 & 0 & \cdots & 0 & s^c_{1.1} & s^c_{1.2} & \cdots & s^c_{1.m} \\ 0 & 1 & \cdots & 0 & s^c_{2.1} & s^c_{2.2} & \cdots & s^c_{2.m} \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 & s^c_{m.1} & s^c_{m.2} & \cdots & s^c_{m.m} \end{bmatrix}$$

Equation (2) defines that the generating matrix G can be divided into two halves. The first half corresponds to an I_m identity matrix of size m , with ones on the principal diagonal and zeros elsewhere. This identity matrix represents the sending phase, in which each node of the network transmits its data, and this is represented by a 1 for each element $s_{i.i}$ where $i \in \{1, m\}$ $s_{i.i}$ .The second half of the matrix G corresponds to the matrix P , which defines the parity equations.

In this way, it is appreciated that in the generating matrix G , each node has two columns, the column i for the transmission in the sending phase and the column $m+1$ for the transmission in the resending phase, which corresponds to a distributed coding.

As shown above, where it is labeled that the first and the n_{m+1}-th column correspond to the two times transmitted by node by node n_1 , one in the sending phase and another in the resending phase. In addition, from the matrix P the central node can construct the parity check matrix H , as indicated in (6):

$$H=\begin{bmatrix} s^c_{1.1} & s^c_{2.1} & \cdots & s^c_{m.1} & 1 & 0 & \cdots & 0 \\ s^c_{1.2.} & s^c_{2.2} & \cdots & s^c_{m.2} & 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots \\ s^c_{1.m} & s^c_{2.m.} & \cdots & s^c_{m.m} & 0 & 0 & \cdots & 1 \end{bmatrix}$$

The bipartite graph regarding a regular parity check matrix H will be used by the SPA to acquire the transmitted information vector.

C. Influence of Parameter β

In order to obtain the best BER, it is necessary to analyze how the value of the parameter β influences the results of the proposed technique and what values of this parameter are valid for this study.

Recall that parameter β corresponds to the number of symbols from the nodes of the group that intervene in the response of each of the nodes during the resending phase. A higher value of this parameter implies that the transmitted symbol includes information about a greater number of nodes, but a very high number may imply that the generator matrix stop being very scattered, increasing the probability of short cycles appearing. This causes the LDPC codes to stop having good properties.

We define the degree of dispersion D as the relationship between the symbols are combined in the resending phase and the number of nodes that can participate in the combination. It refers to the dispersion of the generator matrix G of the LDPC code.

$$D = \beta / m - 1 \tag{9}$$

Before giving the results, we can present the useful parameters values in an attempt to improve our results. The parameters used in our simulation are shown in Table I.

TABLE I. SIMULATION PARAMETERS OF THE FIRST SENDING AND RESENDING PHASES

Designation	***Values***
Node total number	50/100/200/300/400/500
Parameter β	4/6/8/10/12/14/16
Iteration number	10
Power	50 mw
Node Placement	Uniform

IV. RESULTS AND DISCUSSIONS

The main objective of this section is to obtain the parameter values β for the better behavior of the proposed method.

A. Simulation Results

Fig. 2 represents the different curves obtained for a group of 50, 100,200,300,400 or 500 nodes, varying the value of the parameter β and using 10 iterations of the Sum-Product decoding algorithm. The dispersion percentage [10] refers to the dispersion having the generator matrix of the LDPC code.

According to Fig. 2, we note that the increase of the nodes as well as the increase of the parameter causes an increase of the percentage of dispersion. The dispersion percentage presented by the curve of 50 nodes is too high and could be

associated more with dispersed matrices than with very dispersed matrices, so it does not seem a good option to use groupings of this size. we are looking for a compromise between the numbers of the nodes and the value of the parameter for a good value of BER.

Fig. 3 represents the different curves obtained for a different value of parameter β which are 4,6,8,10,12, 14 or 16, varying the value of nodes using 10 iterations of the Sum-Product decoding algorithm.

As shown in Fig. 2 and Fig. 3, parameters β have a crucial role for the dispersion of the elements of the matrix generator.

Fig. 4 shows the different curves obtained for a network containing 100 nodes varying the value of the parameter β .

By analyzing the graphs ,using 100 nodes, we can see that the curves, with greater compromise, are given for the parameter values = 6, 7 and 8, whose matrices offer the dispersion percentage that are displayed in Fig. 2 and Fig. 3.

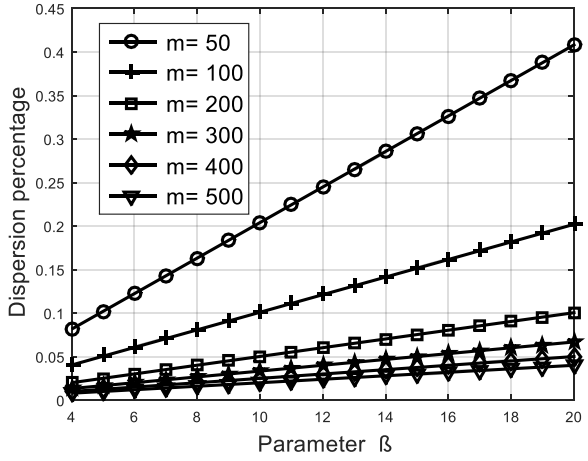

Fig. 2. Dispersion Percentage vs Parameter β using 10 Iterations Selecting different Values of Nodes.

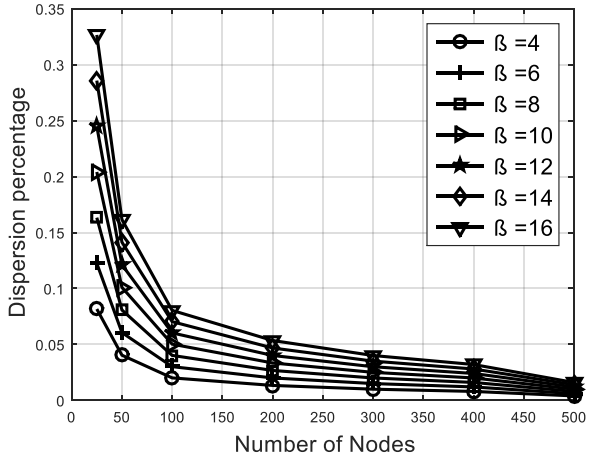

Fig. 3. Dispersion Percentage vs Number of Nodes using 10 Iterations Selecting different Values of Parameter β .

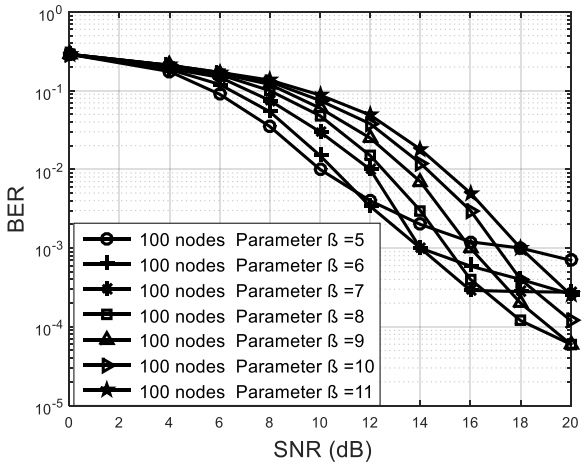

Fig. 4. BER-SNR Curve Obtained for a Distributed LDPC Coding with 100 Nodes. The Parameter β Varies between 5 and 11.

Fig. 5 shows the curves obtained in simulations of 500 nodes, using a maximum of 10 iterations of the decoding algorithm Sum-Product. The parameter β is varied between 8 and 13 and the BER simulation results versus SNR are is represented in Fig. 5 below.

With 500 nodes, the generator matrix of the LDPC code has a size of 500x1000. In addition, the parameter β is varied between 8 and 13 and the BER simulation results versus SNR are shown in the Fig. 5. By observing the resulting graphics to these groups, it can be seen that the curves, that offer a better compromise, are given for the parameter values β comprised between 9 and 12.

For the nodes 200, 300 and 400 nodes we have followed the same procedure as for the nodes 100 and 500 node as shown in Fig. 2 and Fig. 3.

The curves represented in Fig. 6 are the curves that offer better compromise for studied system. By analyzing the curves obtained in Fig. 6, we see that the reliability parameter increases when increasing the nodes number.

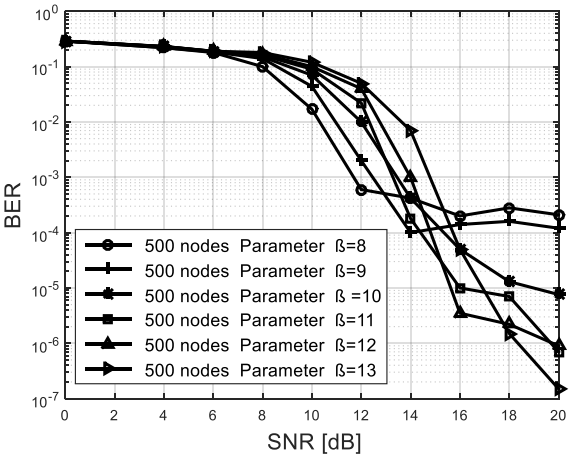

Fig. 5. BER-SNR Curve Obtained for a Distributed LDPC Coding with 500 Nodes. The Parameter β Varies between 8 and 13.

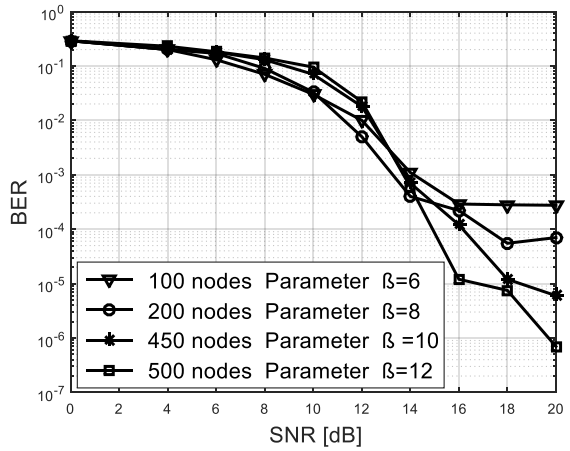

Fig. 6. Comparison of BER-SNR Curves Obtained for a Distributed LDPC Coding which Offers a Better Compromise.

The curves shown in Fig. 6 are the curves that offer the best compromise for each group. In this way, a value of parameter ß= 6 has been selected for a group of 100 nodes. The parameter ß= 8 has been chosen for group of 200 nodes. For group of 450 nodes a value of the parameter is ß= 10 and for group of 500 nodes a value of the parameter is ß= 12.

B. Discussion, Limitations and Future Work

This paper has presented bases of the ANCC scheme using Network Coding with extensive LDPC codes in dense wireless networks based on an efficient technique. The chosen values of the parameter β , obtained for different scenarios with the proposed technique, are a very good compromise to obtain an optimal BER. The number of the selected nodes to a group has an inseparable relationship with the parameter β when applying network coding. The proposed technique results improve the BER performance while maintaining error-free communication with negligible chance of interference.

All the nodes that appeared in the group reached to the central node in a single hop. This scheme facilitated and simplified enough the analysis. But, despite efforts to increase BER in dense wireless networks, this study has a notable limitation crossing several nodes. Consequently, this scheme is difficult to be represented in a real environment because several hops can appear to reach the central node. This depends, among other factors, of the number of nodes, the distance between them and the used technology. The future work is to develop congestion avoidance algorithm improving the BER in central node through several nodes for dense wireless network.

V. CONCLUSIONS

This study investigates the improvement of BER by applying an efficient technique of communication between a central node and a node groups using network coding with LDPC. It focuses most notably on dispersion percentage and the number of the coded symbols correctly received in the resending phase. The authors have been examined and performed different scenarios by selecting the best BER curves versus SNR, with a varying number of nodes and parameters β in the network. The results clearly concludes that the choice of parameters β with their corresponding nodes can improve considerably and significantly the BER versus SNR.

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Entanglement Classification for a Three-qubit System using Special Unitary Groups, SU(2) and SU(4)

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Abstract*—Entanglement is a physical phenomenon that links a pair, or a set of particles that correlates with each other, regardless of the distance between them. Recent researches conducted on entanglement are mostly focused on measurement and classification in multiqubit systems. Classification of two qubits will only distinguish the quantum state as either separable or entangled, and it can be done by measurement. Meanwhile, in a three-qubit system, it becomes more complex because of the structure of the three qubits itself. It is not sufficient to do measurement because the states are divided into three types, including fully separable state, biseparable state, and genuine entangled state. Therefore, the classification is needed to distinguish the type of states in the three-qubit system. This study aims to classify the entanglement of three-qubit pure states using a combination model of special unitary groups, *SU(2)* and *SU(4)*, by changing the angle of selected parameters in *SU(4)* and acting on the separable pure state. The matrix represents *SU(2)* is 2×2 matrix while matrix for *SU(4)* is 4×4 matrix. Hence, the combination of *SU(2)* and *SU(4)* represent 8×8 matrix. This classification uses the von Neumann entropy and three tangle measurements to classify the class, respectively. The results of this study have indicated that the three-qubit pure state has been successfully classified into different classes, namely, *A-B-C*, *A-BC*, *C-AB*, *GHZ*, and *W*, with *A-B-C* being a fully separable state, *A-BC* and *C-AB* are biseparable states, and *GHZ* and *W* are genuine entangled states. The results show that this model can change separable pure states to other entanglement class after transformation is done.

Keywords*—Quantum entanglement; multiqubit entanglement; entanglement classification; special unitary group; three-qubit system; quantum information

I. Introduction

The application of entanglement concept is known to be predominant in quantum computers. This research focuses on three qubits based on the knowledge that the structures of the qubits are more complex and applicable in actuality. This is due to the fact that in reality, quantum computers require more than three qubits to access data during high capacity information transmission. It is shown in the current recent, 20 qubits [1] and 50 qubits have been built and tested by IBM [2]. Throughout the time of entanglement concept's emergence, scientists initially rejected the idea because they were not convinced that entanglement could solve computer problem involving numerous data. However, entanglement became evident in the problem of quantum theory after Einstein, Podolsky, and Rosen (1935) [3-7] succeeded in describing the mysterious phenomenon inherent in quantum mechanics by initiating an experiment, known as the EPR paradox. Despite that, Einstein had doubted the concept of entanglement because the idea did not obey the limit of the speed of light. An assumption was made that the theory of quantum mechanics was incomplete at that time, supported by the fact that he made the second assumption about the existence of hidden variables which were yet to be found. It was also reported that Einstein's assumptions were proven wrong when John Bell [8] succeeded in proving the existence of entanglement in an experiment conducted in 1964 [3, 8, 9].

This research focuses on the classification of entanglement states in a multiqubit system [10-12] for the reason that normal measurements are unable to precisely differentiate the states. Previous research by Yang et al. [3] had only succeeded in classifying the quantum states into either separable, or entangled states due to the nature of structure in two qubits are simpler compared to the structure of multiqubit. Therefore, this research extends the inclusion of three qubits based on the fact that the classification of three qubits takes into consideration three types of state conditions known as fully separable, biseparable, and genuine entangled states [4, 13]. It is a known knowledge that the structure of the three-qubit system [14] is more complicated than the two-qubit system due to the additional parameters in each qubit. Furthermore, it is still equivocal whether the three-qubit structure can or cannot be transformed using local unitary. In order to classify the three-qubit state, various methods were used in the previous study such as the Generalized Schmidt Decomposition (GSD) [5], inductive method [6], special

unitary group (SU), and special linear group (SL) [9, 11, 14, 15]. In spite of that, the classification of three-qubit systems using SU groups is not widely used at current, especially using *SU(2)* and *SU(4)*. Although classification using *SU(2)* has also been done on two qubits and three qubits, studies utilizing the $SU(2)\times SU(2)\times SU(2)$ combination, however only represent one qubit, which could only perform local operations for each qubit without affecting the other one. In addition, the six parameters used in previous study did not allow the selection of parameters to be done [15, 16]. Nonetheless, a complete classification was made for selected simple cases, for example, the $2\times 2\times n$. *SU(4)* system [17, 18] was found to be able to represent two qubits. That being said, the classification of the three-qubit system [19, 20] has not been performed using the combination of *SU(2)* and *SU(4)*.

Therefore, based on the situations mentioned above, in this paper, the classification of three qubits is presented using *SU(2)* and *SU(4)* under local unitary transformation with selected parameters in specific angles from *SU(4)*. This study employs two types of measurements specifically to detect the state either entangled or separable during the classification. First, the von Neumann entropy [19, 21] is given as $S(\rho) = -\mathrm{Tr}\,\rho\log(\rho)$ and the second is the three-tangle [22] measure, τ_3 or also known as the residue entanglement. Three-tangle measure, τ_3 is often used to differentiate between the *GHZ*-state and the *W*-state when these states become genuine entangled state [23, 24]. The three-tangle measure used in this paper is given as, $\tau_3(\varphi) = 4\lambda_0^2\lambda_4^2$, with λ representing the eigenvalues [16, 17].

II. Material and Method

A. Modeling Process

This section explains the process of developing the combination model of $SU(2)$ and $SU(4)$ in details. The step by step process is implemented according to the four main steps as follows:

1) Understand the formula used and the range of angle for each parameter in $SU(2)$ parameterisation and $SU(4)$ parameterisation. The generator for each parameter used in $SU(2)$ and $SU(4)$ also has been studied.

2) Select six variable parameters from $SU(4)$ parameterisation based on the generator used with a fixed parameter used in $SU(2)$. The chosen generator was based on matrix characterisation, which is appropriate to enable the model to be developed. The selected parameters are combined using inner product operation. The range of angle for the parameter was based on the minimum and maximum range for an each of the parameter selected in $SU(4)$. Four combination angles from the range of angles of each parameter are fixed based on these lists:

- Both parameter angles are small, i.e., $\frac{\pi}{12}$.
- The first parameter angle is small, i.e., $\frac{\pi}{12}$ and the second parameter angle is large, i.e., $\frac{\pi}{2}$.
- The first parameter angle is large, i.e., $\frac{\pi}{2}$ and the second parameter angle is small, i.e., $\frac{\pi}{12}$
- Both parameter angles are large, i.e., $\frac{\pi}{2}$

3) Develop a matrix for the combination model of $SU(2)$ and $SU(4)$ operators, i.e., $SU(2)\times SU(4)$ and $SU(4)\times SU(2)$. The operation between $SU(2)$ and $SU(4)$ is a tensor product between the parameter.

4) Develop the operator models $SU(2)\times SU(4)$ and $SU(4)\times SU(2)$, which are implemented on fully separable pure states. The process begins by first combining fully separable pure states with $SU(4)\times SU(2)$ and then combines with $SU(2)\times SU(4)$ to entangle the three qubits.

B. SU(2) Parameterisation

The $SU(2)$ parameterisation [19] is two complex dimensions that describe two level in the quantum system that represented with the 2×2 matrix. The $SU(2)$ parameterisation is given as,

$$U = e^{i\sigma_3\beta_1}e^{i\sigma_2\beta_2}e^{i\sigma_3\beta_3} \tag{1}$$

with $\beta_1, \beta_2, \beta_3$ representing parameters that satisfy the range of rotation angle, $0 \le \beta_1, \beta_3 \le \pi$, and $0 \le \beta_2 \le \frac{\pi}{2}$, with three generators, known as the Pauli matrix:

$$\sigma_1 = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix},\ \sigma_2 = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix},\ \sigma_3 = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \tag{2}$$

C. SU(4) Parameterisation

The $SU(4)$ parameterisation, as proposed by [18], is written as,

$$U = e^{i\lambda_3\alpha_1}e^{i\lambda_2\alpha_2}e^{i\lambda_3\alpha_3}e^{i\lambda_5\alpha_4}e^{i\lambda_3\alpha_5}e^{i\lambda_{10}\alpha_6}e^{i\lambda_3\alpha_7}e^{i\lambda_2\alpha_8}e^{i\lambda_3\alpha_9}e^{i\lambda_5\alpha_{10}}e^{i\lambda_3\alpha_{11}}$$
$$e^{i\lambda_2\alpha_{12}}e^{i\lambda_3\alpha_{13}}e^{i\lambda_8\alpha_{14}}e^{i\lambda_{12}\alpha_{15}} \tag{3}$$

with $\lambda_i, i = 1,2,\ldots,15$ representing the generators. Parameters α_1 until α_{15} are rotation angles of qubits in Hilbert space that satisfy the range:

$$0 \le \alpha_1, \alpha_7, \alpha_{11} \le \pi$$
$$0 \le \alpha_3, \alpha_5, \alpha_9, \alpha_{13} \le 2\pi$$
$$0 \le \alpha_2, \alpha_4, \alpha_6, \alpha_8, \alpha_{10}, \alpha_{12} \le \frac{\pi}{2}$$
$$0 \le \alpha_{14} \le \sqrt{3}\pi$$
$$0 \le \alpha_{15} \le 2\sqrt{\frac{2}{3}}\pi \tag{4}$$

D. Selection of Parameter

This study selected two parameters from operator $SU(4)$ based on the reasoning that they can affect two qubits that are correlated to each other. The two chosen parameters were a combination of six selected parameters, namely; $\alpha_2, \alpha_4, \alpha_6, \alpha_8, \alpha_{10}$ & α_{12} based on the λ_2, λ_5 & λ_{10} generators with selected angles. Some parameters were not chosen in $SU(2)$ since they do not influence other qubits. Besides, the qubit in $SU(2)$ did not have any correlation to the parameters

in $SU(4)$. Parameters that used generators $\lambda_3, \lambda_8, \lambda_{15}$ were not considered since the solution was trivial. Constant parameters were fixed with the value of 0 to ensure that each parameter represented a real number.

E. Matrix Development of Combination Model $SU(2) \times SU(4)$ and $SU(4) \times SU(2)$

This section describes the process of developing the matrix for models $SU(2) \times SU(4)$ and $SU(4) \times SU(2)$. Figure 1 illustrates the three main steps to develop the matrix.

1) Matrix Development for SU(2) and SU(4)

Matrix multiplication for $SU(2)$ as an example for $e^{i\sigma_3\beta_1}$:

$$\begin{aligned} e^{i\sigma_3\beta_1} &= I + i\sigma_3\beta_1 + \frac{(i\sigma_3\beta_1)^2}{2!} + \frac{(i\sigma_3\beta_1)^3}{3!} + \frac{(i\sigma_3\beta_1)^4}{4!} + \cdots \\ &= \cos\beta_1 I + i\sin\beta_1\sigma_3 \\ &= \cos\beta_1\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} + i\sin\beta_1\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \\ &= \begin{pmatrix} \cos\beta_1 + i\sin\beta_1 & 0 \\ 0 & \cos\beta_1 - i\sin\beta_1 \end{pmatrix} \end{aligned} \tag{5}$$

and matrix multiplication for $SU(4)$ as an example for $e^{i\alpha_2\lambda_2}$

$$\lambda_2 = \begin{pmatrix} 0 & -i & 0 & 0 \\ i & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

using generator

$$\begin{aligned} e^{i\alpha_2\lambda_2} &= I + i\alpha_2\lambda_2 + \frac{(i\alpha_2\lambda_2)^2}{2!} + \frac{(i\alpha_2\lambda_2)^3}{3!} + \frac{(i\alpha_2\lambda_2)^4}{4!} + \cdots \\ &= \left(I - \frac{\alpha_2^2}{2!} + \frac{\alpha_2^4}{4!} - \cdots\right)\lambda_2^2 + \left(i\alpha_2 - \frac{i\alpha_2^3}{3!} + \frac{i\alpha_2^5}{5!} + \cdots\right)\lambda_2 \\ &= \begin{pmatrix} \cos\alpha_2 & \sin\alpha_2 & 0 & 0 \\ -\sin\alpha_2 & \cos\alpha_2 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \end{aligned} \tag{6}$$

In this paper, other exponents that were calculated the same as equation (6) were $e^{i\alpha_2\lambda_2}, e^{i\alpha_8\lambda_2}, e^{i\alpha_{12}\lambda_2}, e^{i\alpha_4\lambda_5}, e^{i\alpha_{10}\lambda_5}, e^{i\alpha_6\lambda_{10}}$

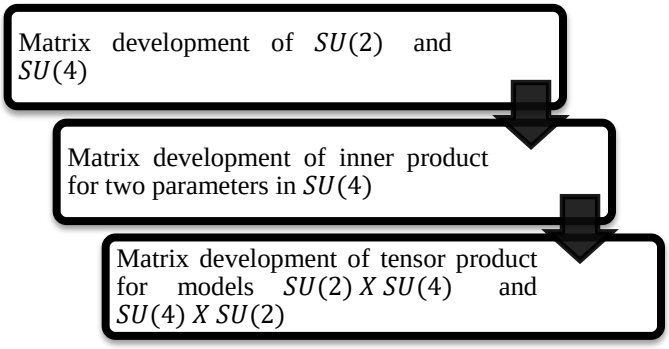

Fig. 1. Steps of Matrix Development.

2) Matrix Development for Two Parameters in SU(4)

From the six selected parameters, two parameters were combined to produce 30 combinations of parameters, as shown in Table I.

An example of matrix multiplication for parameters α_2 and α_4 from two matrixes is as follows, $e^{i\alpha_2\lambda_2}.e^{i\alpha_4\lambda_5}$

$$\begin{aligned} & e^{i\alpha_2\lambda_2}.e^{i\alpha_4\lambda_5} \\ &= \begin{pmatrix} \cos\alpha_2 & \sin\alpha_2 & 0 & 0 \\ -\sin\alpha_2 & \cos\alpha_2 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}\begin{pmatrix} \cos\alpha_4 & 0 & \sin\alpha_4 & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\alpha_4 & 0 & \cos\alpha_4 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \\ &= \begin{pmatrix} \cos\alpha_2\cos\alpha_4 & \sin\alpha_2 & \cos\alpha_2\sin\alpha_4 & 0 \\ -\cos\alpha_4\sin\alpha_2 & \cos\alpha_2 & -\sin\alpha_2\sin\alpha_4 & 0 \\ -\sin\alpha_4 & 0 & \cos\alpha_4 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \end{aligned} \tag{7}$$

For matrix development of the tensor product for $SU(2) \times SU(4)$ and $SU(4) \times SU(2)$, an example for the parameter α_2 α_4 with matrix identity, I_2 for $SU(2) \times SU(4)$ in equation (8). The calculation for $SU(4) \times SU(2)$ in equation (9) using same the parameter of α_2 α_4 with matrix identity, I_2.

$$SU(2)\times SU(4)$$
$$\begin{pmatrix} \cos\alpha_2\cos\alpha_4 & \sin\alpha_2 & \cos\alpha_2\sin\alpha_4 & 0 & 0 & 0 & 0 & 0 \\ -\cos\alpha_4\sin\alpha_2 & \cos\alpha_2 & -\sin\alpha_2\sin\alpha_4 & 0 & 0 & 0 & 0 & 0 \\ -\sin\alpha_4 & 0 & \cos\alpha_4 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \cos\alpha_2\cos\alpha_4 & \sin\alpha_2 & \cos\alpha_2\sin\alpha_4 & 0 \\ 0 & 0 & 0 & 0 & -\cos\alpha_4\sin\alpha_2 & \cos\alpha_2 & -\sin\alpha_2\sin\alpha_4 & 0 \\ 0 & 0 & 0 & 0 & -\sin\alpha_4 & 0 & \cos\alpha_4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \tag{8}$$

$$SU(4)\times SU(2) =$$
$$\begin{pmatrix} \cos\alpha_2\cos\alpha_4 & 0 & \sin\alpha_2 & 0 & \cos\alpha_2\sin\alpha_4 & 0 & 0 & 0 \\ 0 & \cos\alpha_2\cos\alpha_4 & 0 & \sin\alpha_2 & 0 & \cos\alpha_2\sin\alpha_4 & 0 & 0 \\ -\cos\alpha_4\sin\alpha_2 & 0 & \cos\alpha_2 & 0 & -\sin\alpha_2\sin\alpha_4 & 0 & 0 & 0 \\ 0 & -\cos\alpha_4\sin\alpha_2 & 0 & \cos\alpha_2 & 0 & -\sin\alpha_2\sin\alpha_4 & 0 & 0 \\ -\sin\alpha_4 & 0 & 0 & 0 & \cos\alpha_4 & 0 & 0 & 0 \\ 0 & -\sin\alpha_4 & 0 & 0 & 0 & \cos\alpha_4 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \tag{9}$$

The remaining parameters in Table I has been developed by the same multiplication in equation (8) and equation (9) using *MATHEMATICA* software.

F. Operating Flow Chart of Combination Model on Fully Separable Three Qubit Pure State

Figure 2 shows the flowchart of notation $U42$ being used to represent $SU(4) \times SU(2)$ and $U24$ for $SU(2) \times SU(4)$ on fully separable three-qubit pure states. The fully separable three-qubit pure states are represented by $|000\rangle$ and the time interval used is every 10 second.

TABLE. I. COMBINATIONS OF TWO PARAMETERS IN $SU(4)$

No.	Combination	No.	Combination		No.	Combination
1.	α_2,α_4	11.	α_6,α_2		21.	α_{10},α_2
2.	α_2,α_6	12.	α_6,α_4		22.	α_{10},α_4
3.	α_2,α_8	13.	α_6,α_8		23.	α_{10},α_6
4.	α_2,α_{10}	14.	α_6,α_{10}		24.	α_{10},α_8
5.	α_2,α_{12}	15.	α_6,α_{12}		25.	α_{10},α_{12}
6.	α_4,α_2	16.	α_8,α_2		26.	α_{12},α_2
7.	α_4,α_6	17.	α_8,α_4		27.	α_{12},α_4
8.	α_4,α_8	18.	α_8,α_6		28.	α_{12},α_6
9.	α_4,α_{10}	19.	α_8,α_{10}		29.	α_{12},α_8
10.	α_4,α_{12}	20.	α_8,α_{12}		30.	α_{12},α_{10}

The step by step flowchart in Figure 2 is described as follows:

1) Evolution started at $t = 0\,s$, with $U42|000\rangle$ and the first combination of parameters α_2 , α_4 , with the angle of $\alpha_2 = \frac{\pi}{12}$ and $\alpha_4 = \frac{\pi}{12}$

2) At $t = 10\,s$, $U24|\psi\rangle$ began to evolve until $t = 20\,s$, with the same angle in step (i). The newly obtained state was measured using von Neumann entropy and three tangle measurements, which was classified in the list given in Table II. Range value for the von Neumann entropy is $0 \pounds S(r) \pounds 1$ for all values of the density matrix, r with zero value indicating a separable state and one indicating maximum entanglement. For the three-tangle measurement, zero value indicated the *W*-state, while a positive value indicated the *GHZ* state.

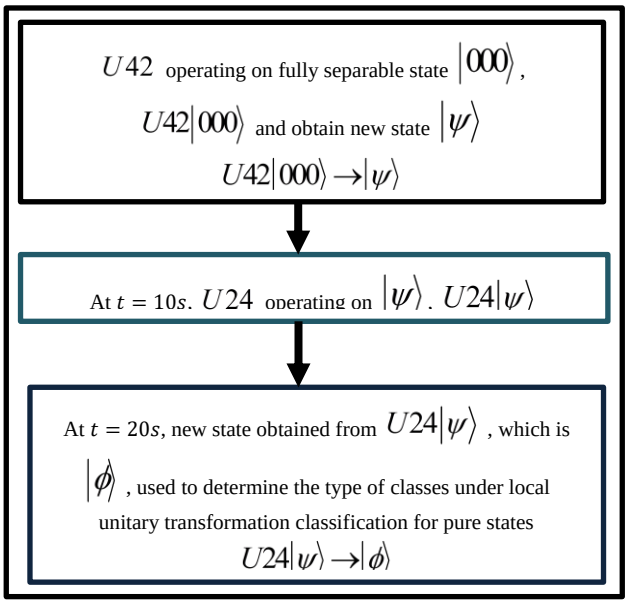

Fig. 2. Operating $SU(2)\times SU(4)$ and $SU(4)\times SU(2)$ on Fully Separable States.

TABLE. II. VON NEUMANN ENTROPY VALUE AND THREE-TANGLE MEASUREMENT

Class	Qubit A, S_A	Qubit B, S_B	Qubit C, S_C	Three tangle, τ_3
$A-B-C$	0	0	0	0
$A-BC$	0	>0	>0	0
$B-AC$	>0	0	>0	0
$C-AB$	>0	>0	0	0
W	>0	>0	>0	0
GHZ	>0	>0	>0	>0

3) Steps (i) and (ii) were repeated with three other angles for the same parameters' combination:

- $\alpha_2 = \frac{\pi}{12}$ and $\alpha_4 = \frac{\pi}{2}$
- $\alpha_2 = \frac{\pi}{2}$ and $\alpha_4 = \frac{\pi}{12}$
- $\alpha_2 = \frac{\pi}{2}$ and $\alpha_4 = \frac{\pi}{2}$

4) Step (i) until (iii) were repeated for all parameters combination, as shown in Table I.

III. RESULTS AND ANALYSIS

The results from the operation of the model to the fully separable states were analysed based on the patterns of von Neumann entropy and values shown in Table II.

A. Patterns of von Neumann Entropy, Before and After the Operation with $SU(2)$ X $SU(4)$

Table III presents the categories for the 30 parameter combinations, which are divided into eight groups, as determined by pattern values of the von Neumann entropy in each combination of parameters in Table I.

B. Classification of Fully Separable Three-qubit Pure State Following Operation by the Model of the Operator $SU(2)\times SU(4)$

The results of this study have indicated that the three-qubit pure state has been successfully classified into different classes, namely; $A-B-C$, $A-BC$, $C-AB$, *GHZ*, and *W*, with $A-B-C$ being a fully separable state, $A-BC$ and $C-AB$ are biseparable states, and *GHZ* and *W* are genuine entangled states. Prior to being combined with $SU(2)\times SU(4)$, the three-qubit pure state could only exist in two types of classes, namely, (i) fully separable state ($A-B-C$) and (ii) biseparable state ($C-AB$). After the combination with $SU(2)\times SU(4)$, the state is turned into five classes, namely, $A-B-C$, $A-BC$, $C-AB$, *GHZ*, and *W*. At combination angles of $\frac{\pi}{2}\,\&\,\frac{\pi}{2}$, the state of the three-qubit is classified into $A-B-C$, before and after being combined

with $SU(2)\times SU(4)$. The combination angles $\frac{\pi}{12}\&\frac{\pi}{12}$ transformed the state from fully separable to genuine entangled state for all groups, except for group 3 and group 7. Group 7 gives a classification class of fully separable states for any combination angles of parameters. Table IV summarises the types of classifications for the pure state of three qubits, before and after being combined with $SU(2)\times SU(4)$ comprising eight groups and four types of combined angles.

TABLE. III. GROUPS OF PARAMETERS COMBINATION

Group	Parameters combination
1	$\alpha_4,\alpha_2,\ \alpha_4,\alpha_8,\alpha_4,\alpha_{12},\alpha_{10},\alpha_2,\alpha_{10},\alpha_8,\alpha_{10},\alpha_{12}$
2	$\alpha_2,\alpha_4,\alpha_2,\alpha_{10},\alpha_8,\alpha_4,\alpha_8,\alpha_{10},\alpha_{12},\alpha_4,\alpha_{12},\alpha_{10}$
3	$\alpha_2,\alpha_8,\alpha_2,\alpha_{12},\alpha_8,\alpha_2,\alpha_8,\alpha_{12},\alpha_{12},\alpha_2,\alpha_{12},\alpha_8$
4	$\alpha_6,\alpha_2,\alpha_6,\alpha_8,\alpha_6,\alpha_{12}$
5	$\alpha_6,\alpha_4,\alpha_6,\alpha_{10}$
6	$\alpha_2,\alpha_6,\alpha_8,\alpha_6,\alpha_{12},\alpha_6$
7	$\alpha_4,\alpha_{10},\alpha_{10},\alpha_4$
8	$\alpha_4,\alpha_6,\ \alpha_{10},\alpha_6$

TABLE. IV. CLASSIFICATIONS OF THREE-QUBIT PURE STATE BEFORE AND AFTER COMBINATION WITH $SU(2)\times SU(4)$

Angle Group	BEFORE COMBINATION WITH $SU(2)\times SU(4)$				AFTER COMBINATION WITH $SU(2)\times SU(4)$			
	$\frac{\pi}{12}\&\frac{\pi}{12}$	$\frac{\pi}{12}\&\frac{\pi}{2}$	$\frac{\pi}{2}\&\frac{\pi}{12}$	$\frac{\pi}{2}\&\frac{\pi}{2}$	$\frac{\pi}{12}\&\frac{\pi}{12}$	$\frac{\pi}{12}\&\frac{\pi}{2}$	$\frac{\pi}{2}\&\frac{\pi}{12}$	$\frac{\pi}{2}\&\frac{\pi}{2}$
1	C-AB	A-B-C	C-AB	A-B-C	GHZ	A-B-C	W	A-B-C
2	C-AB	A-B-C	C-AB	A-B-C	GHZ	A-B-C	GHZ	A-B-C
3	A-B-C	A-B-C	A-B-C	A-B-C	A-BC	A-BC	A-BC	A-B-C
4	C-AB	A-B-C	A-B-C	A-B-C	GHZ	A-B-C	A-B-C	A-B-C
5	C-AB	A-B-C	A-B-C	A-B-C	W	A-B-C	A-B-C	A-B-C
6	C-AB	A-B-C	A-B-C	A-B-C	GHZ	A-B-C	A-B-C	A-B-C
7	A-B-C	A-B-C	A-B-C	A-B-C	A-B-C	A-B-C	A-B-C	A-B-C
8	C-AB	A-B-C	A-B-C	A-B-C	GHZ	A-B-C	A-BC	A-B-C

C. Discussion of the Result

The classification using combinations of special unitary groups, $SU(2)$ and $SU(4)$ is based on three cases of selection on angle in $SU(4)$ parameters which are (i) both angles is small, (ii) one angle is small and another one is big, and (iii) both angle are big. In theory, this study aid in calculating the entanglement that involves three-qubit with considering the changing of the angle at the two-qubit that already correlate in the early combination. By determine the angle, it will make the classification of three-qubit more easy without considering all angle in the early combination. Hence, this study can be extended to the complex state since the state used that is fully separable is the simplest state. Besides, by changing the angle of the parameter, the researcher can fix in the beginning of the process to get the desired result.

IV. CONCLUSIONS

This study has shown that classification using combinations of special unitary groups, $SU(2)$ and $SU(4)$, can be conducted according to the types of the class under the local unitary transformation. It is also found in this study that the three qubits, with fully separable states, can be classified into fully separable states ($A-B-C$), biseparable states ($A-BC, C-AB$), GHZ-like state, and W-like state. This classification has been achieved by considering two main aspects, namely, the group of the parameter's combination in $SU(4)$ and the range of combination angles of the two parameters. Class $A-B-C$ was obtained from group 7, with combination angles of $\frac{\pi}{12}\&\frac{\pi}{2}$, and $\frac{\pi}{2}\&\frac{\pi}{2}$, before and after their combination with the $SU(2)\times SU(4)$ operator. Class *A-BC* was obtained after the operator, $SU(2)\times SU(4)$ from group 3, was combined at combination angles of $\frac{\pi}{12}\&\frac{\pi}{12}$, $\frac{\pi}{12}\&\frac{\pi}{2}$, and $\frac{\pi}{2}\&\frac{\pi}{12}$, while from group 8, the operator was combined at combination angles of $\frac{\pi}{2}\&\frac{\pi}{12}$. Class $C-AB$ was achieved at combination angles of $\frac{\pi}{12}\&\frac{\pi}{12}$ and $\frac{\pi}{2}\&\frac{\pi}{12}$ before being combined with operator $SU(2)\times SU(4)$. In the combination angles $\frac{\pi}{12}\&\frac{\pi}{12}$ from group 1, 2, 4, 6, and 8, the results gave GHZ-like state, while W-like state was obtained for groups 1 and 5 at combination angles of $\frac{\pi}{2}\&\frac{\pi}{12}$ and $\frac{\pi}{12}\&\frac{\pi}{12}$, respectively. These findings have significant implications in understanding how the $SU(2)\times SU(4)$ and $SU(4)\times SU(2)$ operators play the role of transforming the initial state into other classes by only controlling the angle of the parameter in $SU(4)$. With respect to the fact that this study is only limited to fully separable states and does not classify the $B-AC$ class from the simulation, further work needs to be done by considering other parameters combination in $SU(4)$ and other ranges of parameter angles that inlvove real and imaginary value, including changing fully separable states into biseparable states to upgrade the model hence the algorithm become simpler and can be tested in other class of state. Besides, this research also can be extended by combining three parameters that will be changing to see the outcome of the types of class occur.

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Proposal Models for Personalization of e-Learning based on Flow Theory and Artificial Intelligence

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***Abstract*—This paper presents the comparison of the results of two models for the personalization of learning resources sequences in a Massive Online Open Course (MOOC). The compared models are very similar and differ just in the way how they recommend the learning resource sequences to each participant of the MOOC. In the first model, Case Based Reasoning (CBR) and Euclidean distance is used to recommend learning resource sequences that were successful in the past, while in the second model, the Q-Learning algorithm of Reinforcement Learning is used to recommend optimal learning resource sequences. The design of the learning resources is based on the flow theory considering dimensions as knowledge level of the student versus complexity level of the learning resource with the aim of avoiding the problems of anxiety or boredom during the learning process of the MOOC.**

Keywords*—Massive Online Open Course; MOOC; e-learning; flow-theory; learning resource sequence; case based reasoning; reinforcement learning; q-learning

I. Introduction

The e-learning is a teaching-learning process, oriented to the acquisition of a series of competences and skills by the student, characterized by the use of web-based technologies, the sequencing of content and structured activities [1], that since its beginning has had and still has aspects to improve.

In recent years, a huge number of sites have appeared and offer online training and education services, such as: coursera, udacity, udemy, etc. “in press” [2]; the offered courses in these sites, generally MOOCs, which are not far from a traditional classroom course, in the sense that these courses have been planned or prepared considering that all students learn equally, regardless of the level of knowledge or skills that they can have.

Some of the current deficiencies detected in MOOCs are: Instructors and designers of the MOOCs may lack knowledge of the contemporary instructional design principles or learning theories [3]; the access to contents of the learning sessions is linear [4], that is, there is a single sequence of learning resources for all students; the content of the learning resources is structured for all students equally [4], without considering the level of knowledge on the subject that each student has; there is no adequate feedback, it is necessary to clarify misunderstandings or misconceptions [5]. In MOOCs, commonly there is no online tutor or teacher, the student can stagnate because they may not understand properly any resource or learning activity; teaching strategies and the use of learning resources often do not take advantage of the benefits offered by information and communication technologies.

As described above, it generates an inadequate management of learning resources which contributes to an inadequate learning process, generating dissatisfaction in the participants or students, which can culminate in dropout.

Fig. 1 shows what was described above in a problem tree, in such a way that the causes, the problem and the corresponding effects are appreciated for a better understanding.

The solution proposed in the present study focuses on solving the causes mentioned as linear access to contents and non-flexible resources according student's knowledge level, and the personalization of the sequencing of learning resources is considered, for which, in this work, two personalization models are evaluated under similar conditions in order to determine which is the most suitable as a solution according to the results of experimentation.

The first model implements Case Based Reasoning and recommends learning resource sequences that have been successful in the past, Euclidean distance is used to determine similarity between past cases and a new case and recommend a personalized learning resource sequence. In the second model, Q-Learning algorithm of Reinforcement Learning is used to generate an optimal sequence base which is used to recommend a learning resource sequence.

The learning resources were designed considering the flow theory [6], considering the dimensions of the student's level of knowledge and level of complexity of the learning resource. For the present study, resources of two levels of complexity were designed: basic and advanced.

The content of this paper is organized into ten sections, the first of them summarizes the content of this paper, the problem and some causes; the second section shows a review of the state of the art in relation to the problem and the solutions for it; then, the third section, describes the theoretical background necessary for the adequate understanding of the paper content; likewise, in the fourth section, the proposal models in the present work are described; next, in the fifth section, the step by step process for implementing the models is described; in the sixth section, the main features of the MOOC design and the case study are described; in the seventh section, the experimental design used in the study is described; in the eighth section, the results

achieved in the study are shown, also, the results are discussed with similar works; then, in the ninth section, the conclusions reached at the end of the study are shown, and finally the future work section is shown with the improvements that can be made in subsequent works.

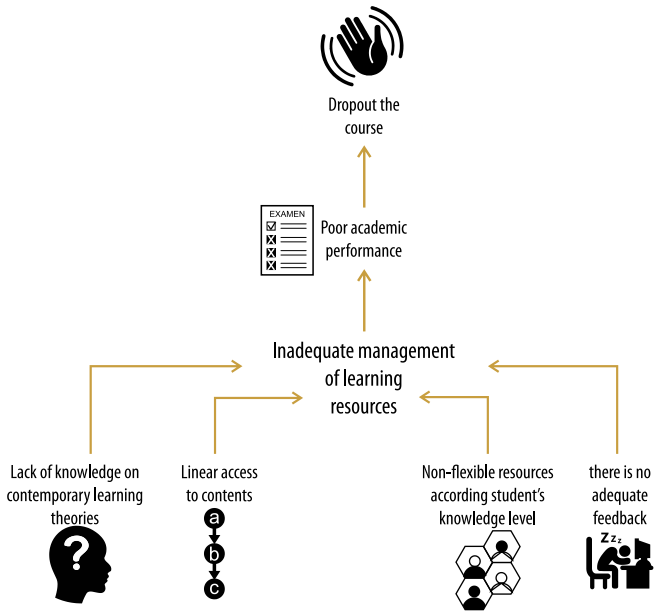

Fig. 1. Dropout in MOOCs.

II. Related Work

A. Proposal Model for e-Learning based on Case based Reasoning and Reinforcement Learning

In this work "in press" [2] the authors proposed a personalized learning management model based on flow theory and Case Based Reasoning and Reinforcement Learning, they used these techniques in a complementary manner. A case of study was implemented working with an experimental group and a control group, the results obtained show that the experimental group achieved a better academic performance with respect to the control group. Authors concluded and highlighted the importance of the personalization of the learning resources sequences in e-learning.

B. Intelligent Model for Personalized Learning Management in a Virtual Simulation Environment based on Instances of Learning Objects

In this work [7], the author presents the results of applying Case Based Reasoning (CBR) to solve the problem of personalization of content in virtual environments. The proposed intelligent learning management system considers Case Based Reasoning for the identification of learning styles and selection of teaching-learning strategies. In the process of identifying learning styles, Case Based Reasoning reached the best classification rate (99.50) compared with other techniques such as Simple Logistic (98.99), Naive Bayes (97.98), Tree J48 (96.98), RN Multilayer Perceptron (94.97). Likewise, in the experimentation process comparing the experimental group with the control group, on a rating scale from 0 to 100, the first reached a general average of 60.5, while the second reached only 39.5, demonstrating the importance of the personalization of contents.

C. Optimization of Personalized Learning Pathways based on Competencies and Outcome

In this work [8], the author formulated the selection of learning routes as an optimization problem based on competencies and evaluation of student learning. The goal was to find the optimal personalized learning path that allows the student to achieve the best possible learning outcome. The author's proposal consists of a course with a set of competences, each competence has associated a set of learning objects, and likewise the competences are associated with evaluation modules that allow measuring the mastery of the competence on the part of the student. The problem was modeled as a Markov Decision Process and the technique or algorithm that was used for its solution were the Temporal Differences included in the set of reinforcement learning techniques, since it is a work in progress, it does not show final results.

D. A Reinforcement Learning-Based Framework for the Generation and Evolution of Adaptation Rules

In this work [9], the authors propose a framework based on Reinforcement Learning (RL) for the generation and evolution of adaptation rules. This framework has two key capabilities for self-adaptation through a two-phase process:

1) The automatic learning capability of adaptation rules from different configurations of objectives in the offline phase (as a result a case base is obtained that includes a set of different configurations of objectives and the corresponding optimal rule sets).

2) The ability of automatic evolution of adaptation rules from real-time information about the environment and user goals in the online phase (As a result, a continually updated case base is obtained that reflects the dynamics of the environment of more precise way and includes a set of possible configurations of objectives with greater degree of coverage). Based on the two capacities, in the online phase, the case that best fits will be recovered from the base of cases to carry out the adaptation, and will be continuously evolved from the actual feedback information.

As it is a work in progress paper, it does not show final results.

E. CBR based Approach for Adaptive Learning in e-Learning System

In this work [10], the authors presented a C Programming based adaptive learning system that removes static learning delivery and accommodates individual student needs and differences to improve their programming learning aspects. This proposal adopts an adaptive approach of four phases based on case base reasoning (CBR) to develop adaptive learning in programming system. On basis of different programming aspects like syntax error, logical error and application usage feasibility, student performance being predicted and impact on their characteristics at different levels are identified.

They concluded that results verify the feasibility and performance of programming learning system using a control and experimental group, where the experimental group had better learning performance than the control group in terms of syntax, logical and application feasibility findings. Individual student needs and differences can be accommodated easily with such personalized adaptive C Programming based e-learning system.

III. Theoretical Background

A. MOOCs

Massive Open Online Courses (MOOCs) are open online courses that generally allow anyone to register and follow the course without a fee (at least for the basic course) [11]. MOOCs, like most online courses, offer learners the flexibility of self-paced learning without the constraints of time and place [12].

To enable self-paced learning, many activities in MOOCs are asynchronous in nature, whereby learners watch a series of videos, take quizzes, or participate in discussion forums. Yet, unlike online courses that offer credits, MOOCs have no enrolment restrictions and can be taken by any interested individual at little or no cost [13]. Therefore, MOOCs have a much larger and more diverse learner population than other online learning environments. In that respect, designing instructions to support the highly diverse learners in MOOCs is important but challenging [13]. The phenomenon of MOOCs has recently attracted considerable attention in the fields of higher education, lifelong learning, and distance education [14].

B. Flow Theory

The flow is a state in which an individual is completely immersed in an activity without reflective self-awareness, but with a deep sense of control. Someone in the flow condition is so focused that he has no room for other thoughts or distractions. The flow theory [6] was initially presented by Mihaly Csikszentmihalyi who used the flow term to represent optimal individual experience focusing on her participation in an activity.

Although the flow was constructed from several complex variables, skill and challenge are the two most important [15]. In general, the theory of flow poses three conditions: the optimal conditions (flow state), the condition of restlessness (anxiety) and the condition of boredom [16]. The optimal condition is achieved when a person's ability is in balance with the given challenge. When the skill required to complete an action or task is lower than the challenging action, learners become anxious or frustrated [17]. When learner skill is higher than the challenging action, learners become bored.

Fig. 2 shows the effect of the relationship between skills and challenge on states of anxiety and boredom.

C. Personalized Learning

In the area of e-learning, "personalization" has a wide range of new meanings. One of the best explanations could be that "personalized learning is the adaptation of pedagogy, curriculum and learning environments to meet the needs and learning styles of individual students" [18].

The subject of personalization is strictly related to the shift from a teacher-centered to a student-centered and competition-oriented perspective. Unlike conventional e-learning, which tends to treat students as a homogeneous entity, personalized e-learning recognizes students as a heterogeneous mix of people [18].

Essentially, personalized e-learning offers students the customization of a variety of elements of the online education process:

- The learning environment: the content and its appearance for the student (such as backgrounds, themes, font sizes, etc.)
- The content of learning itself: multimedia representations (such as text, graphics, audio, video, etc.)
- Interaction: includes facilitator, student and learning content (for example, mouse, keyboard, touch / slide: through questionnaires, online discussions, "games", tutorials, adaptive learning approaches).

D. Case Based Reasoning (CBR)

Given a large set of problems and their individual solutions case based reasoning seeks to solve a new problem by referring to the solution of that problem which is “most similar” to the new problem. Crucial in case based reasoning is the decision which problem “most closely” matches a given new problem [19].

Case-based reasoning (CBR), is a problem to solving paradigm and that utilizes the knowledge of past cases to solve new cases. A past case denotes a previously experienced situation that has been captured and learned, and based from it a new case denotes an unexperienced situation to be resolved [9].

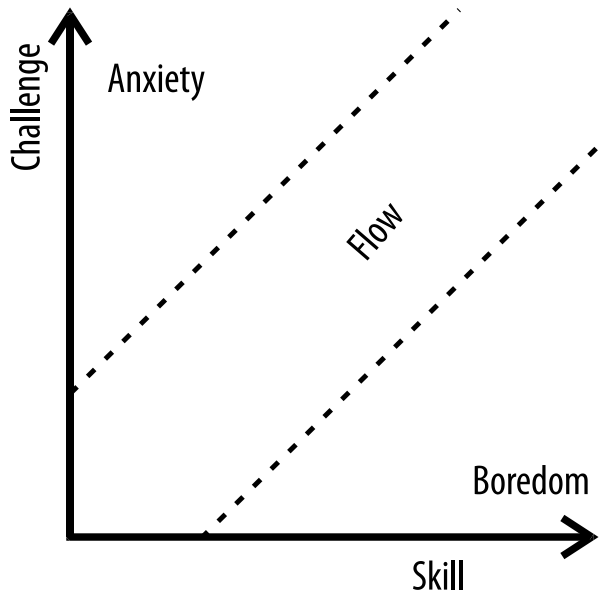

Fig. 2. Flow States.

A past case is stored in a case base, and is characterized from three aspects: 1) Problem description, which depicts the state of the world when the case occurred; 2) Problem solution, which states the derived solution to that problem; and 3) Results, which describes the state of the world after the case occurred [9].

Based in the past cases, a new case is resolved with the following four steps:

1) Retrieve the most similar.

2) Propose a solution to the new case by reusing the information and knowledge in the most similar past case.

3) Revise proposed solution.

4) Retain the information and knowledge of the solution for the new case.

Fig. 3 shows a graphic view of CBR process.

E. Reinforcement Learning

The reinforcement Learning refers to the problem of an agent that aims to learn optimal behavior through trial-and error interactions with a dynamic environment [20]. The algorithms for reinforcement learning share the property that the feedback of the agent is restricted to a reward signal that indicates how well the agent is behaving.

In Reinforcement Learning, the decision-maker, i.e. the agent, interacts with an environment over a sequence of observations and seeks a reward to be maximized over time.

Formally, the model consists of a finite set of environment states *S*, a finite set of agent actions *A*, and a set of scalar reinforcement signals (i.e. rewards) *R*. At each iteration *i*, the agent observes some representation of the environment's state $s_i \in S$. On that basis, the agent selects an action $a_i \in A(s_i)$, where $A(s_i) \subseteq A$, denotes the set of actions available in state s_i. After each iteration, the agent receives a numerical

reward $r_{i+1} \in R$, and observes a new state s_{i+1} [20].

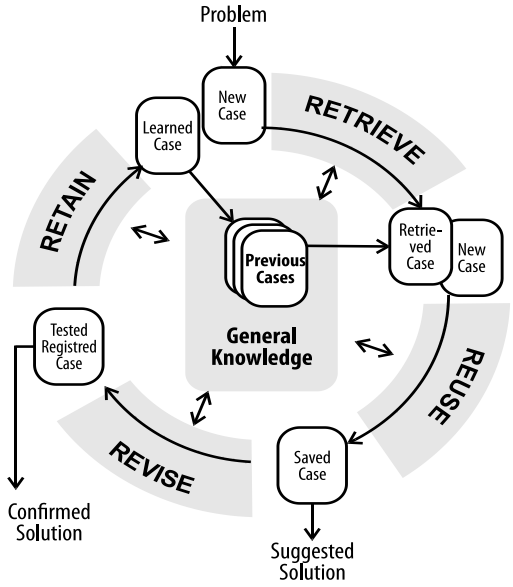

Fig. 3. CBR Process.

In order to store current knowledge, the reinforcement learning method introduces a so-called state-action function $Q(s_i,a_i)$, that defines the expected value of each possible action a_i in each state s_i. If $Q(s_i,a_i)$ is known, then the optimal policy $\pi^*(s_i,a_i)$ is given by the action a_i, which maximizes $Q(s_i,a_i)$ given the state s_i [20]. Consequently, the learning problem of the agent is to maximize the expected reward by learning an optimal policy function $\pi^*(s_i,a_i)$.

F. Q-Learning

Q-Learning [21] is an off-policy method proposed by Watkins to solve Markov Decision Processes (MDP's) with incomplete information. From the point of view of control theory, it is an adaptive direct method, and it is based on the learning of Q according equation (1).

As the agent moves forward from an old state to a new one, Q-Learning propagates the estimates of Q backwards from the new state to the old one.

Although the Q-Learning cycle takes place infinitely in theory, in practice learning is done by episodes (or trials), where each episode begins in a certain initial state until reaching a condition defined by the designer of the learning system (such as: reaching the target state, reaching an absorbing state, exceeding a maximum number of iterations, etc.).

$$Q(s_i,a_i) \leftarrow Q(s_i,a_i) + \alpha \left[r_{i+1} + \gamma \max_{a_{i+1} \epsilon A_{s_i}} Q(s_{i+1},a_{i+1}) - Q(s_i,a_i) \right] \quad (1)$$

Fig. 4 shows Q-Learning algorithm [22].

Initialize $Q(s,a), \forall s \in \mathcal{S}, a \in \mathcal{A}(s)$, arbitrarily, and $Q(terminal\text{-}state,\cdot) = 0$
Repeat (for each episode):
  Initialize S
  Repeat (for each step of episode):
    Choose A from S using policy derived from Q (e.g., ϵ-greedy)
    Take action A, observe R, S'
    $Q(S,A) \leftarrow Q(S,A) + \alpha[R + \gamma \max_a Q(S',a) - Q(S,A)]$
    $S \leftarrow S'$;
  until S is terminal

Fig. 4. Q-Learning Algorithm.

IV. Proposal Models

The proposal models in the present work are very similar, both have four modules, the module COURSE, KNOWLEDGE and E-TUTOR is the same in the two models. The fourth module is different for the two models; the first model (CBR), it is formed by the base of successful sequences; and the second model (RL), it is formed by the base of optimal sequences. In both models, the fourth module contains a sequence retrieval sub-module.

Next, each of the modules of the proposal models is briefly described.

A. Course

This module contains general information of the course, likewise, it contains the base of questions of the pretest and postest, in addition, of the tests of each learning session with the respective solutions.

B. Knowledge

The Knowledge module contains the results of the application of various tests, including the pretest, the postest and the tests of each learning session. The results of these tests are used to implement the base of successful sequences that will be used by CBR and the base of optimal sequences that will be obtained using the Q-Learning algorithm of Reinforcement Learning (RL).

C. E-Tutor

The E-Tutor module contains various learning resources, including educational games (puzzles, crosswords and alphabet soups), videos and PDF documents at basic and advanced levels of complexity. It has a sub-module that implements a learning resource selecting process according proposal models.

D. CBR or RL

This is the main module of our proposals, which contains a base of success cases or a base of optimal sequences, which are required by the E-Tutor module in the learning resource selecting process. For first model, the algorithm of success case retrieving is based on Euclidean distance, and for second model, a random process is used. For the second model, the optimal sequence retrieving is random, considering a higher retrieval probability for the optimal sequences with greater reward. A detailed process is described on next section. Fig. 5 shows proposal model 1 and Fig. 6 shows proposal model 2.

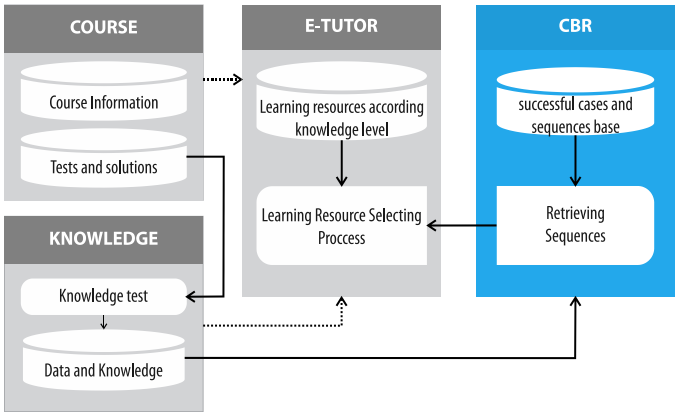

Fig. 5. Proposal Model 1.

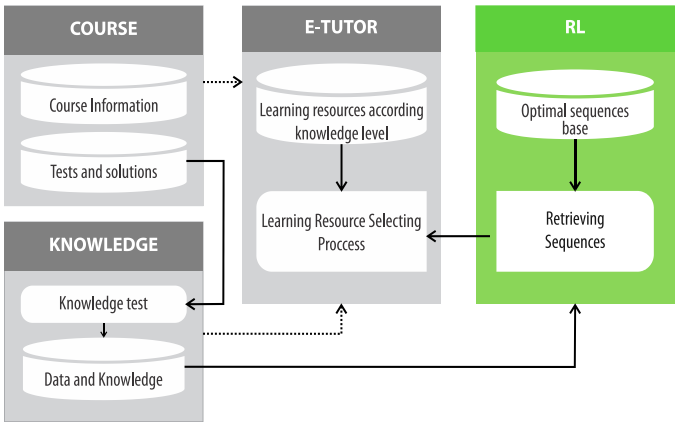

Fig. 6. Proposal Model 2.

V. Process

A topic of general interest was chosen as a case of study to evaluate our proposals, in such a way that a large number of participants could be enrolled in the course; this topic is about Chiribaya Culture and the MOOC was titled “Conociendo la Cultura Chiribaya”, having as a secondary objective of improving cultural identity in the Moquegua region, in the south of Peru.

Fig. 7 shows a summary of process.

1) Application of Pretest: In this stage, a pretest of twenty (20) questions was applied to fifty five (55) students enrolled in the MOOC titled "Conociendo la Cultura Chiribaya".

2) Assignment of sequences randomly: For each learning session, based on pretest results and designed learning resources, all possible sequences were determined and these are assigned randomly to the students according criteria shown in Table I.

In Fig. 8, we can see a graph and possible sequences for first session. Sequence starts at a resource and ends at e resource. For this case; b1, c1 and d1 are basic resources; b2, c2 and d2 are advanced resources; *a* is the session starting resource and e is a quiz about what was learned in this session.

Sessions 2, 3, 5, 6 and 7 have a similar graph, this is shown in Fig. 9 with the difference that the resources were different in the nodes of the graph, as shown in Table II.

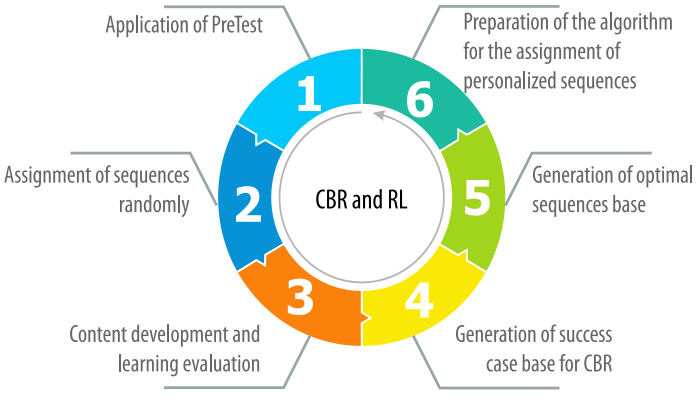

Fig. 7. Process of CBR and RL.

TABLE I. Sequence Assignment Criteria

Pretest Score	Sequences	Resource Level	
		Basic	***Advanced***
[0-5]	a,b1,c1,d1,e	3	0
[6-7]	a,b1,c1,d2,e a,b1,c2,d1,e a,b2,c1,d1,e	2	1
[8-9]	a,b1,c2,d2,e a,b2,c2,d1,e a,b2,c1,d2,e	1	2
[10-20]	a,b2,c2,d2,e	0	3

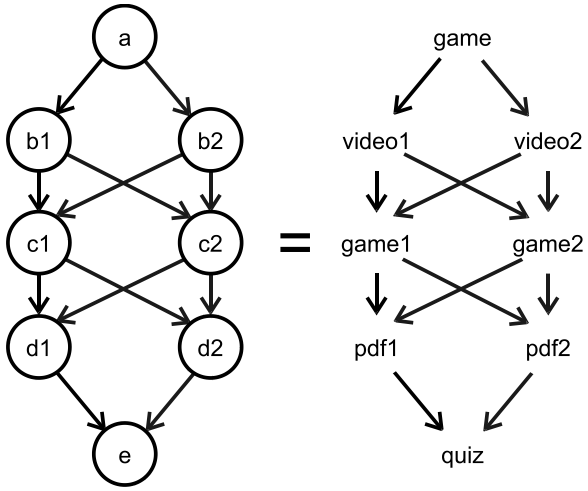

Fig. 8. First Session–Learning Resources Sequence Graph.

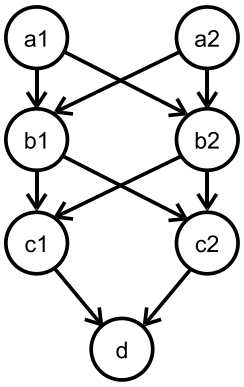

Fig. 9. Graph for Sessions: 2, 3, 4, 5, 6 y 7.

TABLE II. TYPE OF RESOURCES PER SESSION (2,3,4,5,6 AND 7)

Session	a1	a2	b1	b2	c1	c2	d
2	Video1	Video2	Game1	Game2	PDF1	PDF2	Quiz
3	Video1	Video2	Game1	Game2	PDF1	PDF2	Quiz
4	PDF1	PDF2	Game1	Game2	PDF1	PDF2	Quiz
5	PDF1	PDF2	Game1	Game2	PDF1	PDF2	Quiz
6	Video1	Video2	Game1	Game2	PDF1	PDF2	Quiz
7	PDF1	PDF2	Game1	Game2	PDF1	PDF2	Quiz

3) Content development and learning evaluation: Once learning resources sequences were assigned, sessions were developed. Table III shows number of participants who completed course sessions.

TABLE III. STUDENTS PER SESSION

Learning Session	Number of students
1	55
2	51
3	46
4	43
5	40
6	39
7	38

4) Generation of success case base for CBR: The success cases base is generated for each session.

Learning in each session was evaluated with 4 questions, 5 points per question, thus, then possible scores were: 0, 5, 10, 15 or 20. In Table IV, first records of case base are shown.

According to Table IV, for success cases selection, score session was considered. For example, case Id *1* may be eligible as a success case for most sessions, except for session *5*. Similarly, case Id *2* may be eligible as a success case for the first three sessions (1, 2 and 3), but not for the last 4 (4, 5, 6 and 7). Same selection criterion was used for the rest of the cases, besides Euclidean distance.

5) Generation of optimal sequences base: For getting optimal sequences, Q-learning was used, this algorithm generates Q tables and from these tables optimal learning resource sequences for every session were obtained. Table V, shows Q Table for first session. Table VI shows optimal sequences for every session.

TABLE IV. CASE BASE–FIRST CASES

Id	Pretest questions					Score	Session scores						
	1	*2*	*3*	*…*	*20*		*1*	*2*	*3*	*4*	*5*	*6*	*7*
1	1	0	1		0	8	15	15	15	15	10	15	15
2	1	1	0		0	6	15	15	15	0	0	0	0
3	0	1	0		0	3	10	10	10	15	15	15	10
4	1	0	0		0	2	15	15	10	15	15	15	15
5	1	1	0		1	6	15	15	15	15	10	10	15
6	1	1	0		0	5	15	15	10	15	10	15	10
…													

TABLE V. Q TABLE FOR FIRST SESSION

	c1	c2	a	e	b1	b2	d1	d2
.ab1c2d1	0.000000	0.000000	0.000000	0	0.000000	0.000000	0.000000	0.00000
.ab1c2d2	0.000000	0.000000	0.000000	0	0.000000	0.000000	0.000000	0.00000
.ab2c1d1	0.000000	0.000000	0.000000	0	0.000000	0.000000	0.000000	0.00000
.ab1	5.254556	4.857422	0.000000	0	0.000000	0.000000	0.000000	0.00000
.ab2c1d2	0.000000	0.000000	0.000000	0	0.000000	0.000000	0.000000	0.00000
.ab2	5.119506	3.096000	0.000000	0	0.000000	0.000000	0.000000	0.00000
.ab1c1d1	0.000000	0.000000	0.000000	0	0.000000	0.000000	0.000000	0.00000
.ab1c1d2	0.000000	0.000000	0.000000	0	0.000000	0.000000	0.000000	0.00000
.ab2c1	0.000000	0.000000	0.000000	0	0.000000	0.000000	2.561231	0.64000
.ab2c2	0.000000	0.000000	0.000000	0	0.000000	0.000000	0.000000	1.80000
.	0.000000	0.000000	5.668461	0	0.000000	0.000000	0.000000	0.00000
.ab1c1	0.000000	0.000000	0.000000	0	0.000000	0.000000	2.750853	1.00000
.ab1c2	0.000000	0.000000	0.000000	0	0.000000	0.000000	2.721600	3.68928
.a	0.000000	0.000000	0.000000	0	5.517102	6.367814	0.000000	0.00000
.ab2c2d1	0.000000	0.000000	0.000000	0	0.000000	0.000000	0.000000	0.00000
.ab2c2d2	0.000000	0.000000	0.000000	0	0.000000	0.000000	0.000000	0.00000

TABLE VI. OPTIMAL SEQUENCES

Learning Session	Optimal Sequences
1	a,b2,c1,d1,e a,b1,c1,d1,e
2	a2,b1,c1,d a1,b2,c1,d
3	a2,b2,c2,d a1,b1,c1,d
4	a1,b2,c1,d
5	a2,b1,c2,d
6	a1,b2,c1,d a2,b1,c2,d
7	a1,b1,c1,d a2,b1,c2,d

6) Preparation of the algorithm for the assignment of personalized sequences: At this stage, once success cases base and optimal sequences base were built, two algorithms were implemented, one for each proposal model.

For the proposal model 1:

a) First, the algorithm receives as input (the problem), a vector of correct and incorrect answers from student's pretest.

b) Second, the input vector is compared with each case, according similarity determined by Euclidean distance (2).

$$d(p,q) = d(q,p) = \sqrt{(q_1 - p_1)^2 + (q_2 - p_2)^2 + \dots + (q_n - p_n)^2}$$

$$= \sqrt{\sum_{i=1}^{n} (q_i - p_i)^2} \quad (2)$$

Table VII shows implementation of Euclidean distance algorithm in PHP language.

Thus, when the student logs in or enters the MOOC, the sequences of learning resources of each session or topic are loaded into a matrix, that is accessed according to the student's interaction with the MOOC interface. Learning resource sequence matrix can be seen in Fig. 10.

TABLE VII. EUCLIDEAN DISTANCE ALGORITHM IN PHP

```
function euclidean_distance($v1,$v2)
{
        $s=0.0;
        $nv=count($v1);
        for($i=0;$i<$nv;$i++)
        {       $d=(int)$v1[$i]-(int)$v2[$i];
                $s+=pow($d,2);
        }
        return sqrt($s);
}
```

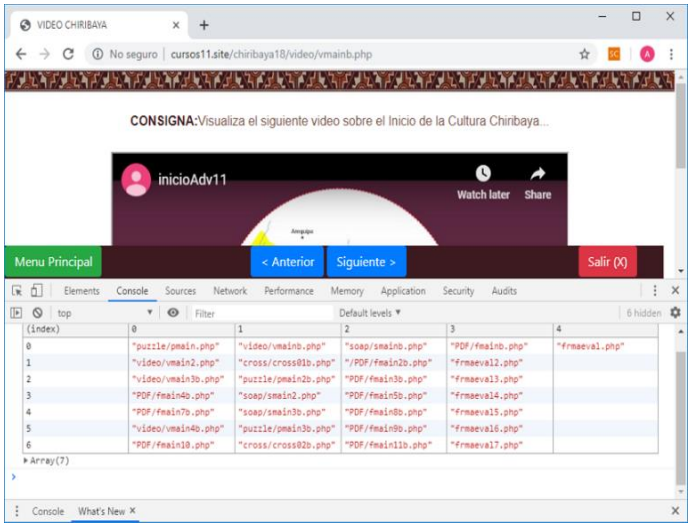

Fig. 10. Learning Resource Sequence Matrix for a Student.

For the proposal model 2:

a) First, the algorithm receives as input (the problem), a vector of correct and incorrect answers from student's pretest.

b) Second, a sequence from optimal sequence base is randomly assigned; ensuring that sequences with highest reward have a higher occurrence.

VI. MOOC DESIGN

The MOOC of the Chiribaya Culture was designed with the contents shown in the Table VIII.

Fig. 11 shows main screen of Chiribaya Culture MOOC.

Fig. 12 shows some educational games designed for the MOOC. Also, Table IX shows the fundamental differences between basic and advanced resources in the designed MOOC.

The learning resources are accessed by the students according to the learning resource sequence determined by CBR or RL module corresponding to proposal model 1 or proposal model 2, respectively.

TABLE VIII. MOOC CONTENT

Content	Learning Resources
Pretest	Pretest
1. Inicio	Game, Video, Game, PDF, Quiz
2. Agricultura	Video, Game, PDF, Quiz
3. Ganadería	Video, Game, PDF, Quiz
4. Textilería	PDF, Game, PDF, Quiz
5. Cerámica	PDF, Game, PDF, Quiz
6. Pesca y Recolección	Video, Game, PDF, Quiz
7. Momias	PDF, Game, PDF, Quiz
Postest	Postest

Fig. 11. Chiribaya Culture MOOC–Main Screen.

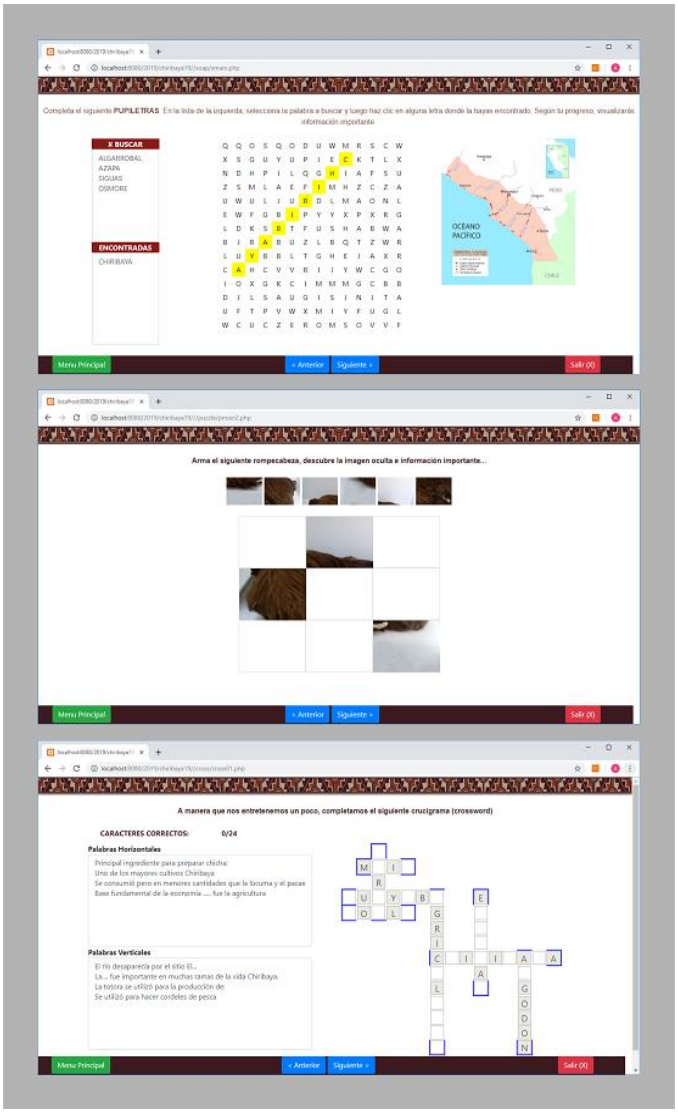

Fig. 12. MOOC's Educational Games: Alphabet Soup, Puzzle and Crossword.

Table X shows some learning resources with the exact difference between basic and advanced level in different MOOC learning sessions.

TABLE IX. DIFFERENCES BETWEEN BASIC AND ADVANCED RESOURCES

Learning resource		Basic Level	Advanced Level
Video		Less time Less content	More time More content
PDF		Less pages Less content	More pages More content
Game	Crossword	Less words	More words
	Alphabet Soup	Less words Smaller matrix	More words Bigger matrix
	Puzzle	Less pieces	More pieces

TABLE X. BASIC AND ADVANCED RESOURCES EXAMPLES

Learning session	Learning resource		Basic Level	Advanced Level
I	Video		1.35	1.58
III	PDF		2 pages	4 pages
II	Game	Crossword	6 words	8 words
II		Alphabet Soup	4 words Matrix 13x13	6 words Matrix 14x14
IV		Puzzle	6 pieces	9 pieces

VII. EXPERIMENTAL DESIGN

Once the process was completed, an experiment was carried out with the following experimental design:

EG1 O1 X1 O2
EG2 O3 X2 O4

CG O5 O6

Where:

EG1 : Experimental Group 1
O1 : Experimental Group 1 Pretest
O2 : Experimental Group 1 Postest
X1 : Proposal Model 1
EG2 : Experimental Group 2
O3 : Experimental Group 2 Pretest
O4 : Experimental Group 2 Postest
X2 : Proposal Model 2
CG : Control Group
O5 : Experimental Group 3 Pretest
O6 : Experimental Group 3 Postest
X3 : Proposal Model 3
CG : Control Group
O5 : Control Group Pretest
O6 : Control Group Postest

Likewise, the number of students that participated in each group is shown in Table XI.

Experimental results are described on section Results and Discussion.

TABLE XI. NUMBER OF STUDENTS PER GROUP

Group	Number of students
Experimental Group 1 (EG1)	11
Experimental Group 2 (EG2)	10
Control Group 1 (CG)	15

VIII. RESULTS AND DISCUSSION

Results were organized in two dimensions: Academic and Technical. For the academic dimension we will analyze some statistics of academic performance of the students under proposal models, the results of the pretest and postest were evaluated on the scale from 0 to 20; and in the technical dimension we will analyze a common metric to evaluate effectiveness of recommended sequences by proposal models, such as precision.

A. Academic Results

According to Table XII, comparing the mean of the pretest with the mean of the postest, it is appreciated that the proposal model 1 (CBR), reached the highest performance, a total of 7.81 points of increase. Second, we have the proposal model 2 (RL) with an increase of 7.5 points.

Likewise, the two models for personalization of learning resources sequences obtained superior performances regarding not using personalization in the MOOC that obtained an increase of just 5.93 points.

Fig. 13 shows graphically the mean differences between the described proposal models, and Fig. 14 shows a mean comparison of Experimental Groups with Control Group.

TABLE XII. COMPARISON OF PROPOSAL MODELS

Statistics / Technique	Mean		Deviation	
	Pretest	Postest	Pretest	Postest
CBR	5.64	13.45	3.17	3.39
RL	6.1	13.6	2.6	2.95
No personalized	5.40	11.33	1.96	1.95

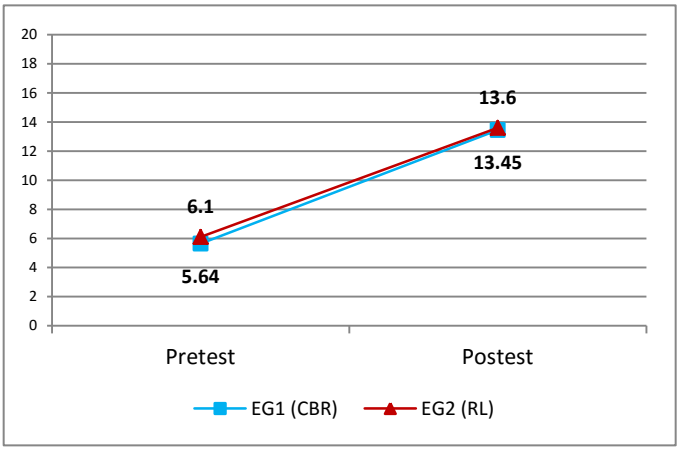

Fig. 13. Mean Comparison of Pretest versus Postest.

Comparing the standard deviation of the pretest versus the postest, in the CBR model an increase in dispersion of 0.22 points is observed, while in the RL Model the increase is greater 0.35 points.

Results of proposal models in this work were compared with proposal model of paper "in press" [2], Fig. 15 shows a better academic performance of hybrid CBR+RL model proposed “in press” [2], we attribute this difference with respect to proposal models to the use of optimal sequences in a complementary manner when the CBR success case base does not contain enough cases.

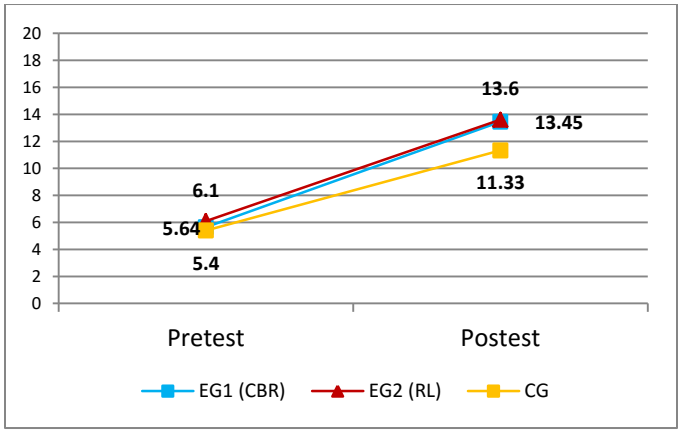

Fig. 14. Mean Comparison between Experimental Groups and Control Group.

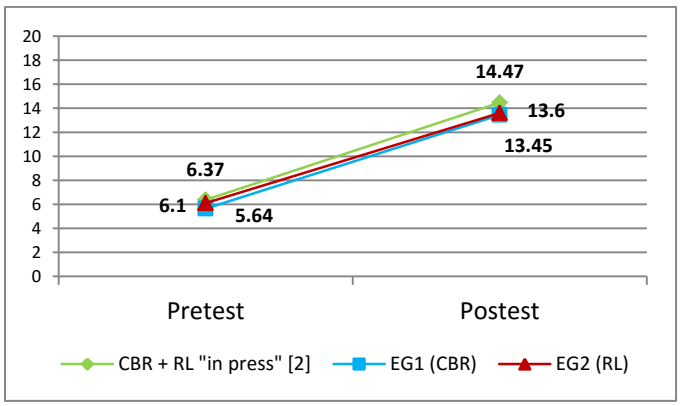

Fig. 15. Mean Comparison between Proposals Models Versus CBR+RL Model “in press” [2].

However, despite not having managed to overcome the results of the CBR + RL model “in press” [2], the results of the proposal model 1 and proposal model 2 are very promising, since despite the small number of cases (55) the academic results were very close to the CBR + RL model, we consider that, with a greater number of cases, results of the proposal model 1 could equal or exceed the hybrid model. In addition, it is necessary to work with larger samples, 10 or 11 students are not enough.

Also, we compared results of proposal models with results of work [7], which was based on the personalization of content based on student learning styles and Case Based Reasoning. In a Kinematics course, 100 students were evaluated on a scale of 0 to 100, where the postest average

reached 60.5 points, which converted to a scale of 0 to 20 equals 12.1 points, which is lower than those obtained by our proposal models 13.45 and 13.6 respectively, although the greater complexity of the Kinematics course with respect to our case study should be highlighted.

B. Hypothesis Contrast

For the hypothesis contrast, the normality tests of Shapiro-Wilk [23] and Anderson-Darling [24] were first applied to the experimental groups, in both cases the samples passed the tests, so the hypothesis contrast was performed with the Welch Two Sample T – Test [25].

Our hypothesis are:

H_0:True difference in means of proposal model 1 and proposal model 2 is equal to 0

H_1:True difference in means of proposal model 1 and proposal model 2 is not equal to 0

Considering a significance level: $\alpha = 0.05$; and running the t.test function from R software we obtain the results shown in Fig. 16.

According to Fig. 16, since p-value > α (0.9174>0.05), H_0 is accepted.

The mean of the Experimental Group 1's population is considered to be equal to the mean of the Experimental Group 2's population or the difference between the mean of the Experimental Group 1 and Experimental Group 2 populations is not big enough to be statistically significant.

C. Technical Results

In this part, it is very important to analyze effectiveness of retrieved sequences by our proposals, for it, the summary in Table XIII was elaborated. Equation (3) was used to calculate precision metric.

$$Precision = \frac{\#\text{true positives}}{\#\text{true positives}+\#\text{false positives}} \quad (3)$$

The Precision indicates how well retrieved sequences match student's interest. It is the ratio of the number of relevant sequences retrieved to the total number retrieved.

```
        Welch Two Sample t-test

data:  muestraX and muestraY
t = -0.10513, df = 18.974, p-value = 0.9174
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -3.041435  2.750526
sample estimates:
mean of x mean of y
 13.45455  13.60000
```

Fig. 16. Results of Welch Two Sample T-Test in R.

TABLE XIII. EFFECTIVENESS OF PROPOSAL MODELS

Proposal Model	Precision
CBR	0.909
RL	0.900

According Table XIII, a precision comparison of proposal models was made, observing that the proposal model 1 (CBR) reached the highest precision 0.909, with respect to the proposal model 2 (CBR) that reached a precision of 0.90. In this aspect, the proposal model 1 outperforms the proposal model 2.

IX. CONCLUSIONS

We conclude that personalization based on flow theory considering knowledge level of the students and complexity level of resources is very important to improve the academic performance in MOOCs. In the two proposal models, a higher academic performance was achieved respect the traditional linear access strategy (non-personalized) offered from most MOOC sites of the two proposal models, for the study case of the Chiribaya Culture teaching, the proposal model that achieved the best academic performance was the second one, the based on Reinforcement Learning and the proposal model who achieved the best precision of the recommended learning resource sequences was the first one, the based on Case Based Reasoning. We must emphasize that there is no significant statistical difference between the means of both proposal models.

X. FUTURE WORK

The proposal models can be improved by working with a bigger number of students (55+) used for the training phase and during the development of the course it was decreasing until get 38 students. Dropout is a big problem in most MOOCs [26]. So, it was no possible to have a good size for the successful sequence base.

It would be important to analyze the personalization proposals in other more complex teaching areas such as Mathematics, Physics, etc.

Also, models presented on this work can be improved, updating structure variables of cases, containing not only pretest questions, but also considering other aspects of flow theory as challenge, control, focused attention, presence, flow and positive affect [27].

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Evaluation of LoRa-based Air Pollution Monitoring System

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Universiti Kebangsaan Malaysia (UKM)[2, 3]

***Abstract*—Air pollution is a threat to human health and the environment. Pollution caused by harmful gases emitted from car exhausts, factories, forest fires and other sources. Carbon monoxide, nitrogen oxides and carbon dioxide are the main elements of air pollution. Serious air pollution may cause harm to our health, thus, a real-time air pollution system to measure existing pollution is needed to classify the pollution level so that appropriate actions can be taken. In a high density area, a big number of sensor nodes are deployed to cover such places and to allow high range communication between nodes and a gateway. This paper presents a real-time and long range air pollution monitoring system for indoor and outdoor environments. The system implemented a wireless sensor network using LoRa technology for data communication between all nodes and sensors. The system consists of three nodes distributed within 900m distance to gateway for measuring the concentration of carbon monoxide, carbon dioxide and nitrogen oxide. Experimental results show the system is reliable in both indoor and outdoor applications. The distance coverage achieved up to 900m and can be displayed through a web-based system. The experiment with LoRa transmission has shown that the LoRa technology is very suitable for the air pollution system especially in long range transmission compared to other wireless transmission techniques.**

***Keywords*—Air pollution; carbon monoxide; wireless sensor network; LoRa; communication; gateway; transmission**

I. Introduction

Air pollution has become a threat to the human being as it contains harmful gases from various sources. Exposure to air pollution in open areas accounts for about 3 million deaths per year, and indoor air pollution can cause the same number of deaths. In 2012, indoor and outdoor air pollution was estimated at 6.5 million deaths (11.6% of the world total). 90 per cent of deaths from air pollution in low- and middle-income countries cause two out of three deaths in South-East Asia and the Western Pacific. Air pollution causes health risks, including cardiovascular disease, stroke, lung cancer and respiratory infections according to world health organization [1]. Malaysia is one of the emerging countries in Southeast Asia facing the challenges of air pollution like other countries in the world. Among the factors that have led to increased air pollution in Malaysia are industrial growth, construction, forest, fires, car fumes and transport, as well as the problem of fog and smoke from the southwest monsoon of forest fires in Indonesia [2]. Air is spread with harmful contaminants such as carbon monoxide, carbon dioxide and nitrogen oxides and is spread both in the open environment and the closed environment. Hence, the importance of the design of the air quality measurement system is flexible and expandable to measure pollutants both in the open or closed environment and provide the user with the value of the pollution existing in one place or several places at the same time.

Air Pollutant Index (API) for health classifications in Malaysia is divided into five categories, each one with a colour and specific value. Classifications are (good, moderate, unhealthy, very unhealthy, and serious) [3]. Traditional air pollution measurement systems lack flexibility and deployment because they are large, stable and require specialized personnel to conduct measurements, in addition to the high cost of creating an air pollution measurement system [4]. With the advent of wireless transmission technologies and sensors, the design of an air pollution measurement system, where sensors and inexpensive Internet of Things (IoT) techniques were used to detect pollution and configuration of wireless networks at remote locations are possible [5].

II. Related Works

Previous studies have been focusing on the integration of the IoT and wireless transmission techniques in monitoring applications. In [6], they implemented a sensor node consists of microcontroller 18F4550 with sensors CO2, O2, SO2-D4, CO, NO2, temperature and humidity. The data were sent to the gateway by Zigbee modules. The disadvantages of this system are that the use of Zigbee technology as a mean of transmitting data between the sensor node and gateway. Zigbee technology is limited to about 100 meters' transmission and consumes high energy. In [7], the study has introduced a mobile node designed to be placed in a vehicle and the data of the pollution sensor were sent in real-time. The use of this method is very expensive in addition to the continuous payments due to its dependence on the mobile network; furthermore, the weakness of the cellular network in the traffic areas and the absence of network coverage in rural areas.

The wireless network provides an alternative solution where it consists of nodes distributed in different places in a closed environment. These nodes transmit pollution data depending on the sensors attached to each node to the base station [8], Moreover, these nodes use low power controllers. However, this system is costly and required all nodes to be

working to provide the total measurement in the enclosed environment. Another solution is using GPRS-based system as in [9], it was designed to measure polluting gases: carbon monoxide, carbon dioxide and sulphur dioxide. Data are displayed in the Google Maps interface, the study has used to the 16-bit microcontroller and air pollution sensors: carbon dioxide, NO2, sulphur dioxide, GPS module and GPRS modem. The disadvantage of this system is that the measuring air pollution process takes place in an open area and relying on cellular network technology. This reliance has many disadvantages like the limited coverage of the cellular network, the weak mobile network in rural or remote areas, and high cost.

With the advances of network technology in wireless sensor networks (WSN), air quality measurement systems would rather be designed to send data to the main gateway or base node to collect sensors data. It WSNs consists of several sensor nodes scattered in large areas based on wireless communication. The function of the sensor node is to measure physical phenomena such as temperature and humidity with limited memory [10]. The sensor node, in terms of physical components, consists of a wireless transmitter/receiver, an embedded processor, internal and external memory, a power source and sensors [11]. There are many algorithms that regulate wireless network operations in terms of sending data from different nodes [12]. Sensor node has the ability to process data and storage. It contains sensors and each node has the ability to generate, analyse and direct data to a certain point. Wireless sensor networks are used in many applications like agricultural, industrial, medical and others [13]. WSN collects information from different sensors in large and small networks so that end users can access and process data. These networks can be used to monitor people's health, weather conditions, traffic control and air pollution [14]. WSN consists of the base station, where these sensor nodes sense data from the environment and direct data back to the base station either through a single hop or multiple hop technology that is sent to the user via other secondary links [15].

LoRa is a long-range wireless communication protocol transfer rates range between 290 bps and 50 kbps. LoRa peripherals are used to communicate with gateways. LPWAN (Wide-Area Low Power Area Network) technologies are increasingly on-demand [16]. LoRa is a low-power wireless network protocol (LPWAN) in a wide area for Internet Objects (IoT) applications. The effective, long-term, cost and power of LPWANs make this technology the most suitable for smart city applications [17]. Low-Power Area Networks (LPWANs) are the types of networks that are used to connect Internet objects from a wide range of sectors. These types of technologies provide devices internet objects (IoT) the ability to transfer a small number of data to long ranges, taking into consideration the minimum power consumption [18]. Some 2.4 GHz wireless technologies such as Bluetooth, Wi-Fi and Zigbee consume a lot of power and only support the transmission range between the nodes and the gateway for up to 100 meters [19]. Therefore, if nodes are to be deployed to detect pollution in a large area, using a 2.4 GHz technology, the node battery will not be enough to be used without recharging continuously. The deployment of a wireless sensor network based on this technology will be expensive and ineffective. In addition, when using these nodes within a wireless network spread over wide distances, the biggest problem we face is the limited distance of communication because if we want a distance greater than 100 meters, it will require frequent gates to re-send or receive data to increase the coverage area. This means that increasing the number of gates to cover a larger distance will result in a direct increase in the cost of the project.

This paper focuses on the configuration of a wireless network that contains two important aspects: energy and cost. The system is distinguished by low power, long coverage and long battery life due to our reliance on LoRa transmission technology. We propose a system for data observation and air pollution analysis in indoor and outdoor environments. Pollution measurement data can be collected from different locations by connecting to a special site. We use LPWAN and LoRa for this purpose and we rely on Malaysia API classification in the classification of measured pollution.

III. Proposed System

This section shows the structure of the system and the explanation of the physical components used in the project. The nodes in this system are responsible for detecting pollution and used three sensors to measure carbon monoxide, carbon dioxide and nitrogen oxides. The nodes are deployed in different areas; thus, they provide enough information on the percentage of pollution and classify them based on API Malaysia. The node sends data to the gateway. The data collected by the gateway are analysed and presented to users in an easy-to-use platform. A sensor node is made from the Arduino UNO R3 microcontroller board. This is the main part of the system, where all the codes used to regulate the work and the functions of the components attached will be stored. The advantages of the system presented in this study are low cost, easy to use and microcontroller based on ATmega328. For the sensors, the study used three sensors (MQ7-MQ2-MQ135), sensors have been selected as they can detect major gases in case of pollution: carbon monoxide, carbon dioxide and nitrogen oxides. The range of detection of gas sensors ranges from 10 ppm to 1000 ppm and from 10 ppm to 300 ppm, respectively.

The transmitter module used in the study is RFM LoRa Shield, it is compatible with Arduino. It allows users to send data and access to extremely long ranges at low data rates (<50 kbps). LoRa shields Provide long-range connectivity with diffusion spectrum and high immunity to interfering with current consumption reduction [20]. In the power module, the study used 1200 mA 3.7-volt rechargeable Li-ion battery**.** For the second part of the system, the gateway is responsible for collect data of the nodes; we used RFM LoRa Shield with Arduino as is shown in Fig. 1.

To visualize the data, we created a web page to display the pollution information. The information was displayed in a local server where they can be available on-site and mobile-related applications as shown in Fig. 2. The system displays the rates of carbon monoxide, carbon dioxide and nitrogen oxides pollution with a hazard rating according to the global standard in Malaysia. Also, they will be aware of the

proportions of those gases in the air. This system provides accurate information, which has been tested in the indoor and outdoor environment, to identify the quality of gases in the air that causes pollution and thus can take actions to reduce those sources. The system will provide information at the lowest cost. The user interface is simple to use and understandable. The system will update the data every minute from different locations.

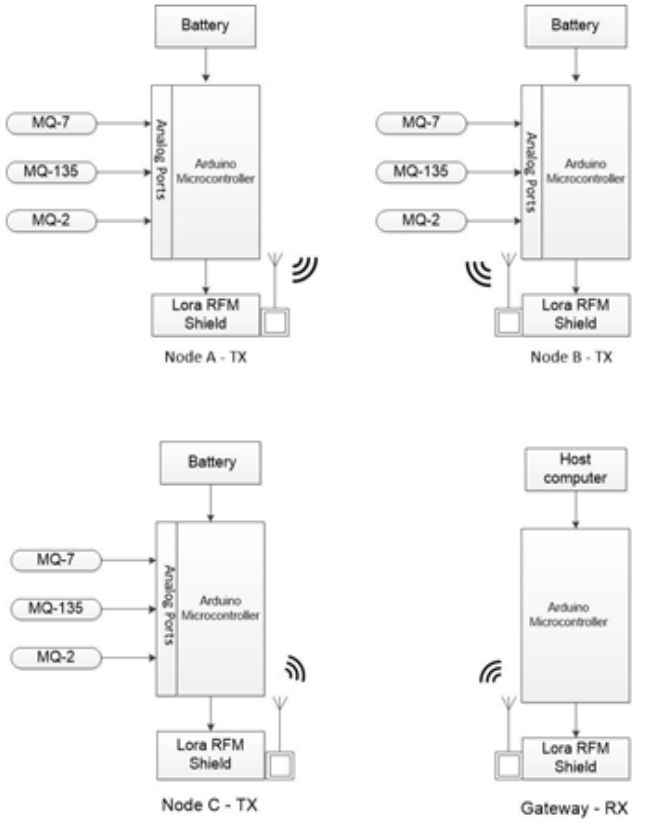

Fig. 1. Air Pollution Monitoring System.

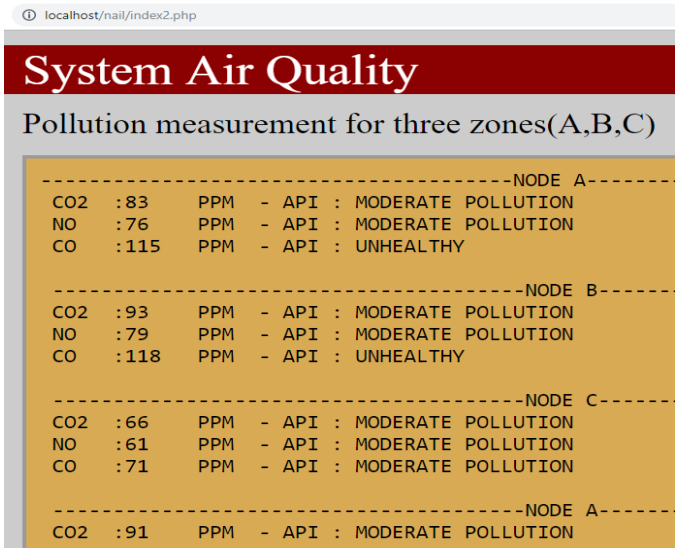

Fig. 2. Web-Based user Interface.

This system is capable of detecting and classifying pollution, by establishing a wireless sensor network to provide information, requires avoiding the disadvantages of previous measurement systems in terms of using wireless communication technologies between network components. Traditionally, this type of network can be configured, but multiple gateways are needed because of limited of wireless transmission. All nodes were deployed at different distances to measure pollution in real-time. Data is obtained every one minute from the nodes that are published and collected by the gateway. The collected data were stored in a text file which represents the database on the hard drive and then transfers it to end-users through a local server.

IV. Results and Discussion

In this study, four experiments are conducted: (A) validation of the proposed system to measure pollution by sensors and the ability of the wireless network to send and receive data between the nodes and the gateway, (B) pollution measurements in an outdoor environment, (C) pollution measurements in indoor environment and (D) maximum distance coverage for LoRa data transmission between the nodes and the gateway.

A. Pollution Classification

The system was first tested where the sensors connected to node A were exposed to some pollutants gradually, and the data was sent wirelessly to the gateway. Fig. 3 shows the systematic classification of the pollution measured by the sensors according to the degree of measured pollution. The results show the ability of the system to record the level of pollutions.

B. Outdoor Environment

Two experiments were conducted to test the system in the outdoor environment. The first experiment is in University Kebangsaan Malaysia (UKM) Campus and in Kajang city centre.

1) A. UKM campus experiment: In this experiment, three nodes were deployed in different areas to measure pollution. Node A was placed at a crossroads opposite the main gate of UKM University, node B was placed on the main road in the campus and node C was placed at the building Dewan Canselori Tun Abdul Razak (DECTAR) as shown in Fig. 4. Fig. 5 illustrates the distance between all three nodes and the gateway at UKM University.

The results collected by gateway showed that node A, which was located at a crossroads outside UKM University, has the highest in pollution measurement compared to the other two nodes where the pollution with carbon dioxide is 43 ppm, carbon monoxide and nitrogen oxides are 19 ppm. The pollution was classified as “good low pollution”. Pollution within the university area measured in B and C is classified as "good low pollution", the lowest level of pollution was in node C (CO2 = 4 ppm, NO = 12 ppm, CO = 11 ppm) as the building is far from the main road which contributes to low pollution rates. Fig. 6 presents pollution measurement results from three nodes.

```
----------------------------------------NODE A------------
SENSOR MQ135 :238   PPM  - API :very UNHEALTHY
SENSOR MQ2   :170   PPM  - API : UNHEALTHY
SENSOR MQ7   :95    PPM  - API : MODERATE POLLUTION

----------------------------------------NODE A------------
SENSOR MQ135 :381   PPM  - API : HAZARDOUS
SENSOR MQ2   :161   PPM  - API : UNHEALTHY
SENSOR MQ7   :142   PPM  - API : UNHEALTHY

----------------------------------------NODE A------------
SENSOR MQ135 :312   PPM  - API : HAZARDOUS
SENSOR MQ2   :163   PPM  - API : UNHEALTHY
SENSOR MQ7   :119   PPM  - API : UNHEALTHY

----------------------------------------NODE A------------
SENSOR MQ135 :373   PPM  - API : HAZARDOUS
SENSOR MQ2   :232   PPM  - API : VERY UNHEALTHY
SENSOR MQ7   :166   PPM  - API : UNHEALTHY
```

Fig. 3. Air Pollution Measurement and Classification.

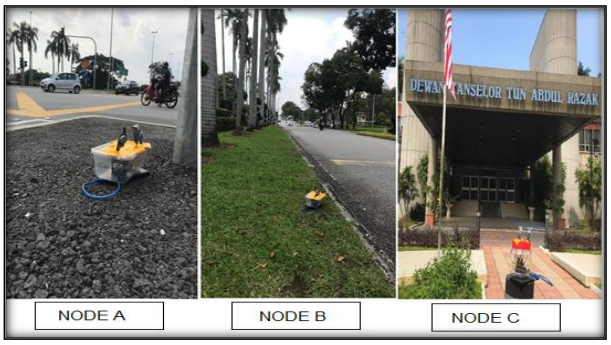

Fig. 4. Placement of Nodes in UKM Campus.

Fig. 5. Distance between Nodes and Gateway in UKM University.

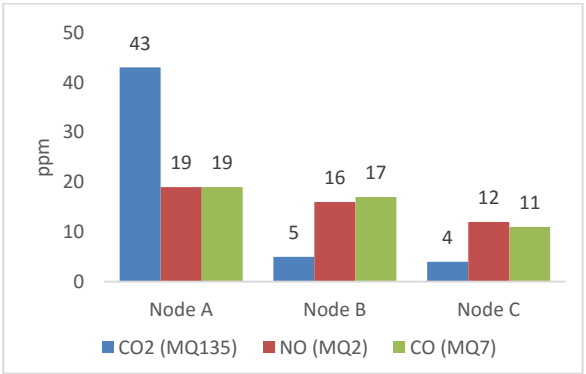

Fig. 6. Pollution Sensor Reading in UKM Campus.

Fig. 7. Node A and Gateway Location in Kajang City Centre.

2) B. Kajang city center: An experiment was conducted to measure pollution in Kajang area that has many people, with a variety of activities and with more vehicles on the road. All sensors attached to the nodes provide information on the gases reading in this area. Fig. 7 shows the placement of nodes at the main street near the Kajang MRT station (SBK34). The recorded pollution data are shown in Fig. 8. It is shown that the pollution of carbon dioxide was 82 ppm while the pollution with nitrogen oxides was 65 ppm and carbon monoxide was 52 ppm, thus, the pollution level was classified as moderate. A higher pollution level is recorded as the node is next to the main road where traffic congestion is high most of the time.

C. Indoor Experiment

Another testing was performed in an indoor environment with less air circulation, such as offices, classrooms and libraries that use central air conditioning where windows and doors are closed. The sources of pollution come from carbon dioxide associated exhaled while breathing, central air, or the use of air fresheners. Pollution measurements were placed in the faculty library as illustrates in Fig. 9, which contained halls of different sizes. Two halls were chosen for the experiments, a hall with (3 x 6 m) size with the presence of three students and the other one hall with a (5 x 15 m) size with a presence of four students, the library uses central air conditioners where windows and doors inside the halls are closed.

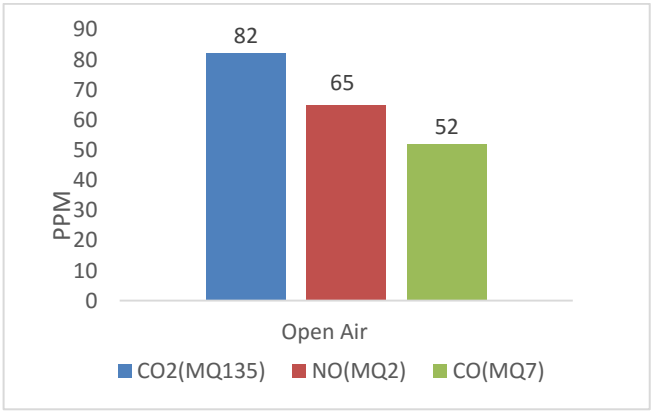

Fig. 8. Pollution Sensor Reading in Kajang City Centre.

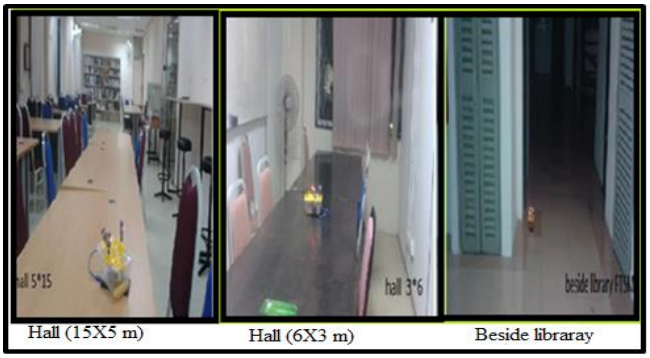

Fig. 9. FTSM Library Halls Selected for the Experiment.

3) A. Hall (5x15 m): Node A was placed outside a library to measure outdoor pollution whereas node B was placed in a 75-meter closed hall with 3 students while node C was placed in a hall of the same size but without students. The gateway was placed inside the library to receive sensor data from the three nodes.

The results showed that during the presence of three students in the hall, the carbon dioxide ratio was 32 ppm with a slight increase in the ratio of carbon monoxide and nitrogen oxides. This was classified as a low pollution level and is classified as good. Carbon dioxide was detected in the closed due to student respiration, while the ratios of carbon monoxide and nitrogen oxides were equal to those in the air. Fig. 10 shows the proportions of pollution measured by nodes.

4) B. Hall (6x3 m): Node A was placed outside the library while node B was placed in a closed hall of 18 m with 3 students while node C was placed in a hall of the same size but without students. The gateway was placed inside the library to receive sensors data from the three nodes. The results showed that the pollution of nitrogen oxides and carbon monoxide in the library was caused by internal indoor pollution. The nitrogen oxides and carbon monoxide inside the library were equal to those found in open-air measured by node A. The outdoor carbon dioxide ratio was 10 ppm. In the hall with the three students, a 47ppm ratio was measured by node B due to breathing. The room was empty and the reading rose to 47 ppm in the hall with the three students because of the breath measured by node B. In another situation where the hall was empty, the ratio of carbon dioxide decreased to 27 ppm compared with student's hall and became 20 ppm as shown in Fig. 11.

D. LoRa Data Transmission

An experiment was conducted at the UKM Stadium to assess the scope of the LoRa transmission coverage. The experiment was conducted at a different football field where the ground was flat and contained trees and buildings. The temperature was 36°C, the humidity was 86%. The gateway was placed at the end of the field and the knot started from a distance of zero to 1.1 km. The number of packets received from the node is counted for 2 minutes at 100 meters. The measurement was conducted in 12 locations (from 0 to 1100 m) as shown in Fig. 12. The experiment showed that the reception rate was 100% at a distance of 0 to 900 m. There were no missing packets. After that distance (900 m), there was a loss rate of 95% at 1 km and 1.1 km. The loss of the number of packets increases after 900 m as shown in Fig. 13.

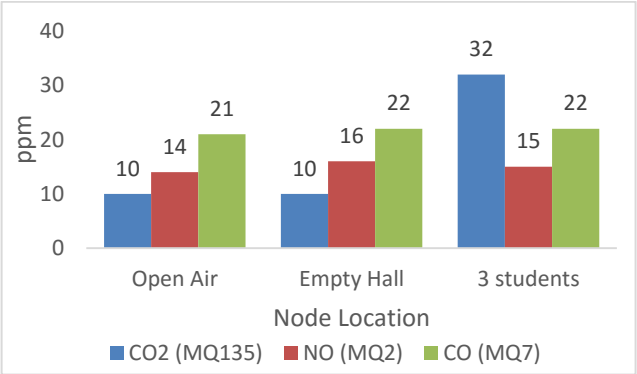

Fig. 10. Air Pollution in the Hall (5x 15m).

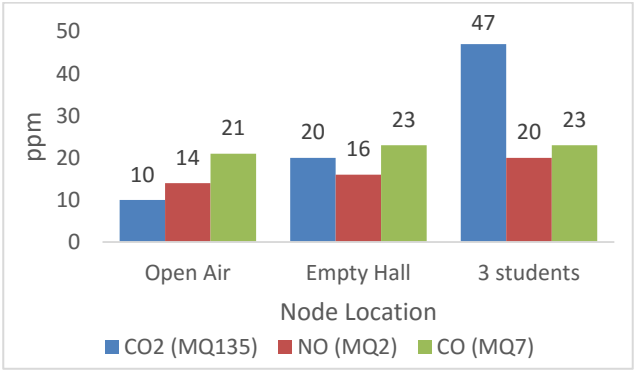

Fig. 11. Air Pollution in the Hall (6X3m).

Fig. 12. Route of the LoRa Performance Test.

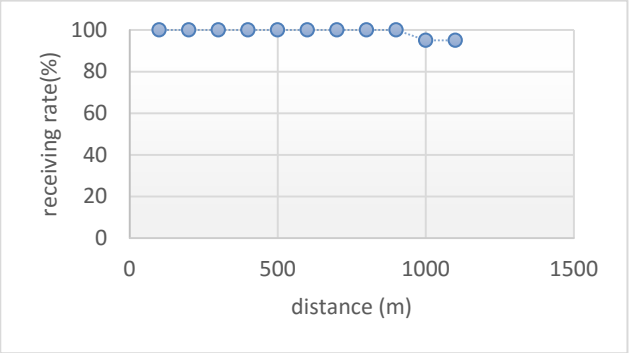

Fig. 13. LoRa Receiving Rate between Gateway and Node.

V. Conclusion and Future Works

The proposed environmental pollution monitoring system has overcome many of the disadvantages of traditional pollution measurement systems, which also rely on wireless transmission technologies that are no more than 100 meters' coverage, such as Zigbee and Wi-Fi. The proposed system is a low-cost system, does not require any phone/data bills as for cellular-based system, small size, long coverage and transmitting in real-time. Based on the practical experiments in the indoor and outdoor environment, the system has proven its ability to detect pollution and classify its pollution level. The experiment with LoRa transmission has shown that LoRa technology is very suitable for the air pollution system especially in long-range transmission compared to other wireless transmission techniques.

Future studies can focus on enhancing the coverage of LoRa technology by adding more gateways in traffic-congested areas. In addition, new types sensors can be added to detect other relevant types of gases.

Acknowledgment

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New Quintupling Point Arithmetic 5P Formulas for Lŏpez-Dahab Coordinate over Binary Elliptic Curve Cryptography

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***Abstract*—In Elliptic Curve Cryptography (ECC), computational levels of scalar multiplication contains three levels: scalar arithmetic, point arithmetic and field arithmetic. To achieve an efficient ECC performance, precomputed points help to realize a faster computation, which takes away the need to repeat the addition process every time. This paper introduces new quintupling point (5P) formulas which can be precomputed once and can be reused at the scalar multiplication level. We considered mixed addition in Affine and Lŏpez-Dahab since the mixed addition computation cost is better than the traditional addition in Lŏpez-Dahab coordinates over binary curve. Two formulas are introduced for the point quintupling which (*Double Double Add*) and (*Triple Add Double*), the cost of the two formulas are 17 multiplication + 12 squaring and 23 multiplication + 13 squaring respectively. The two formulas are proven as valid points. The new quintupling point can be implemented with different scalar multiplication methods.**

***Keywords*—Elliptic Curve Cryptosystem (ECC); scalar multiplication algorithm; point arithmetic; point quintupling; Lŏpez-Dahab (LD); binary curve**

I. Introduction

Elliptic curves cryptosystem (ECC) was proposed by Neal Koblitz and Victor Miller independently in 1985 for the public-key cryptographic system [1]. Similar to other public key cryptographic algorithms, elliptic curve cryptosystem deploys a public key and private key. The public key is used for encryption to provide data confidentiality during communication. ECC is implemented in smart card because of its smaller key size and less computational complexity relative to RSA cryptosystem [2] and [3]. This makes it attractive and suitable for such applications [4].

Working on ECC, scalar multiplication contains three levels of computation such as scalar arithmetic, point arithmetic and field arithmetic [5] as shown in Fig. 1. Scalar arithmetic is to find the value of kP=P+P+…+P (k times) where k is binary. Point arithmetic contains the operations on the point in ECC such as doubling and addition. Finally, field arithmetic contains the operations to calculate the scalar multiplication such as addition, squaring, multiplication and inverse in the field.

Point arithmetic layer is the operations on the point in ECC. Precomputed points help to realize a faster computation which takes away the need to repeat the addition process every time [6]. The operations comprise of point addition (Q+P), point doubling (2P), point tripling (3P), point quadrupling (4P), point quintupling (5P), point septupling (7P) and so on.

Different precomputed quintupling point 5P have been proposed in different coordinates over different curves. A new 5P is proposed by [7] for Jacobian coordinates over prime field where the coefficient in the general equation $a \neq 3$, the cost of the proposed point is $15M + 10S$, where M and S are multiplication and squaring respectively. This point over the same coordinate, condition and curve has been improved. In [8], they optimized formula is of the cost $8M + 16$. Recently, two optimized formula are proposed for the previous point in [9] and [10], where the cost of the formulas are $10M + 14S$ and $8M + 16S$ respectively.

Over Edward curve in the prime field, different point quintupling 5P formulas are proposed. In [11], the authors proposed a formula of the cost $17M + 7S$. This formula is improved by [10] with cost of $15M + 9S$. On the other hand, over the binary field, a new point quintupling is proposed using λ projective coordinate by [12], with the cost of $13M + 8S$, the authors had shown up that there is no point quintupling 5P formula for the general binary curve in López-Dahab (LD) coordinate.

The contributions of this paper are as follows: Two point arithmetic formulas for López-Dahab coordinate are proposed over the general binary curve using mixed addition and doubling [13] method. The first point is of form $5P = 3P + 2P$ (Tripling addition to doubling) of cost $23M + 13S$. An enhancement to this point is proposed using the form $5P = 2(2P) + P$ (Doubling doubling addition to point) of cost $17M + 12S$. The two formulas are validation proved.

The remainder of this paper is organized as follows: Section 2 discusses the related work, while Section 3 introduces the proposed algorithms, cost analysis and the validation proof. While, conclusion and future works are presented in Section 4.

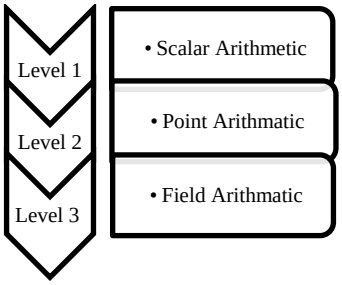

Fig. 1. Computational Levels in ECC Scalar Multiplication.

II. Related Works

General binary curve (short Weierstrass curve) as follows [14]:

$$E: y^2 + \text{xy} = x^3 + \ ax^2 \ + \ b \tag{1}$$

where the projective point $(X:Y:Z)$ and $Z \neq 0$ defined over LD projective coordinates has the equation:

$$Y^2 + XYZ = X^3 + aX^2Z^2 + bZ^6 \tag{2}$$

Point addition for LD first proposed by [15] as in Algorithm 1 of costs $14M + 6S + 8A$.

Algorithm 1: The projective form of two points adding formula in LD coordinate where $(X_1, Y_1, Z_1) + (X_2, Y_2, Z_2) = (X_3, Y_3, Z_3)$ is:

$A_0 \leftarrow Y_2Z_1^2$ $\quad D \leftarrow B_0 + B_1$ $\quad H \leftarrow CF$

$A_1 \leftarrow Y_2Z_2^2$ $\quad E \leftarrow Z_0Z_1$ $\quad X_3 \leftarrow C^2 + H + G$

$B_0 \leftarrow X_2Z_1$ $\quad F \leftarrow DE$ $\quad I \leftarrow D^2B_0E + X_3$

$B_1 \leftarrow X_1Z_2$ $\quad Z_3 \leftarrow F^2$ $\quad J \leftarrow D^2A_1 + X_3$

$C \leftarrow A_0 + A_1$ $\quad G \leftarrow D^2(F + aE^2)$

$\text{Y}_3 \leftarrow \text{HI} + \text{Z}_3\text{J}$

For the special case where $Z_2 = 1$, this formula can be improved as:

$(\text{X}_1, \text{Y}_1, \text{Z}_1) + (\text{X}_2, \text{Y}_2, 1) = (\text{X}_3, \text{Y}_3, \text{Z}_3)$

$\text{A} \leftarrow \text{Y}_2\text{Z}_1^2 + \text{Y}_1$ $\quad \text{E} \leftarrow \text{AC}$

$\text{B} \leftarrow \text{X}_2\text{Z}_1 + \text{X}_1$ $\quad \text{X}_3 \leftarrow \text{A}^2 + \text{D} + \text{E}$

$\text{C} \leftarrow \text{Z}_1 + \text{B}$ $\quad \text{F} \leftarrow \text{X}_3 + \text{X}_2\text{Z}_3$

$\text{D} \leftarrow \text{B}^2(\text{C} + \text{aZ}_1{}^2)$ $\quad \text{G} \leftarrow \text{X}_3 + \text{Y}_2\text{Z}_3$

$\text{Z}_3 \leftarrow \text{C}^2$ $\quad \text{Y}_3 \leftarrow \text{EF} + \text{Z}_3\text{G}$

To reduce the cost of point arithmetic, a formula involving parameters such as A_0, D, T, … amongst others can be used to calculate the parameters X_3, Y_3, and Z_3.

This formula has been improved by [16] where the authors reduced the cost to be $13M + 4S + 9A$ using the formula as in Algorithm 2.

Algorithm 2: The projective form of two points adding formula in LD coordinate where $(X_1, Y_1, Z_1) + (X_2, Y_2, Z_2) = (X_3, Y_3, Z_3)$ is:

$\text{A} \leftarrow \text{X}_1\text{Z}_2$ $\quad \text{E} \leftarrow \text{A} + \text{B}$ $\quad \text{I} \leftarrow \text{G} + \text{H}$

$\text{B} \leftarrow \text{X}_2\text{Z}_1$ $\quad \text{F} \leftarrow \text{C} + \text{D}$ $\quad \text{J} \leftarrow \text{IE}$

$\text{C} \leftarrow \text{A}^2$ $\quad \text{G} \leftarrow \text{Y}_1\text{Z}_2^2$ $\quad \text{Z}_3 \leftarrow \text{FZ}_1\text{Z}_2$

$\text{D} \leftarrow \text{B}^2$ $\quad \text{H} \leftarrow \text{Y}_2\text{Z}_1^2$

$\text{X}_3 \leftarrow \text{A}(\text{H} + \text{D}) + \text{B}(\text{C} + \text{G})$

$\text{Y}_3 \leftarrow (\text{AJ} + \text{FG})\text{F} + (\text{J} + \text{Z}_3)\text{X}_3$

A new formula for point addition using mixed addition in affine LD coordinate is proposed by [13], with cost of $9M + 5S + 9A$ as shown in Algorithm 3.

Algorithm 3: The projective form of two points P and Q adding formula where $(X_1, Y_1, Z_1) + (X_2, Y_2, Z_2) = (X_3, Y_3, Z_3)$ such that $Z_1 = 1$, P is in affine and Q is in LD coordinate is given as:

$\text{A} \leftarrow \text{Y}_2 + \text{Y}_1\text{Z}_2^2$ $\quad \text{B} \leftarrow \text{X}_2 + \text{X}_1\text{Z}_2$

$\text{C} \leftarrow \text{BZ}_2$ $\quad \text{Z}_3 \leftarrow \text{C}^2$ $\quad \text{D} \leftarrow \text{X}_1\text{Z}_3$

$\text{X}_3 \leftarrow \text{A}^2 + \text{C}(\text{A} + \text{B}^2 + \text{aC})$

$\text{Y}_3 \leftarrow (\text{D} + \text{X}_3)(\text{AC} + \text{Z}_3) + (\text{Y1} + \text{X1})\text{Z}_3^2$

Doubling of point P is the operation of adding the point to itself as $P + P = 2P$. Over LD coordinate, the first doubling formula is proposed by [15] with cost of $5M + 4S + 5A$ as presented in Algorithm 4.

Algorithm 4: The projective form of point doubling formula in LD coordinates where $2(X_1, Y_1, Z_1) = (X_2, Y_2, Z_2)$ is given as:

$\text{A} \leftarrow \text{Z}_1^2$ $\quad \text{B} \leftarrow \text{bA}^2$ $\quad \text{C} \leftarrow \text{X}_1^2$

$\text{Z}_2 \leftarrow \text{AC}$ $\quad \text{X}_2 \leftarrow \text{C}^2 + \text{B}$

$\text{Y}_2 \leftarrow (\text{Y}_1^2 + \text{aZ}_2 + \text{B})\text{X}_2 + \text{Z}_2\text{B}$

The projective form of point doubling formula in LD coordinate given in Definition 4 is modified by [17], by adding one field addition while reducing one field squaring, so the total cost of the improved formula is $5M + 4S + 5A$ as presented in Algorithm 5.

Algorithm 5: The projective form of point doubling $2P$ formula in LD coordinate system is given as:

$\text{A} \leftarrow \text{X}_1^2$ $\quad \text{B} \leftarrow \text{A} + \text{Y}_1$ $\quad \text{C} \leftarrow \text{X}_1\text{Z}_1$

$\text{D} \leftarrow \text{BC}$ $\quad \text{Z}_2 \leftarrow \text{C}^2$ $\quad \text{X}_2 \leftarrow \text{B}^2 + \text{D} + \text{aZ}_2$

$\text{Y}_2 \leftarrow (\text{Z}_2 + \text{D})\text{X}_2 + \text{A}^2\text{Z}_2$

The operation of adding a point P to itself three times is a point tripling, such that $3P = P + P + P$. Tripling point can also take the form of the addition of a point with a point doubling such that $3P = 2P + P$. The lowest cost point tripling over LD coordinate is proposed by [18], as shown in Algorithm 6, the cost of the tripling formula is $12M + 7S$, where addition operation is neglected since it has the cheapest field arithmetic cost [19].

Algorithm 6: The point $3P = (X_3, Y_3, Z_3)$ is tripling for $P = (X_1, Y_1, Z_1)$ where $3P = 2P + P$ has the formula as:

The point $2P = (X_2, Y_2, Z_2)$ is doubling for $P = (X_1, Y_1, Z_1)$ where [17]:

$S \leftarrow X_1^2 \quad U \leftarrow S + Y_1 \qquad T \leftarrow X_1 Z_1$

$R \leftarrow UT \; Z_2 \leftarrow T^2 \qquad X_2 \leftarrow U^2 + R + aZ_2$

$Y_2 \leftarrow (Z_2 + R)X_2 + S^2 Z_2$

The point $3P = (X_3, Y_3, Z_3)$ is tripling

$A \leftarrow (Z_2 + E)X_2 + Z_2^2 + UB \leftarrow X_2 + X_1 X_2$

$C \leftarrow BZ_2 C \leftarrow BZ_2 Z_3 \leftarrow C^2 \qquad D \leftarrow X_1 Z_3$

$E \leftarrow UX_1 \qquad X_2 \leftarrow U^2 + E + aZ_2$

$X_3 \leftarrow A^2 + C(A + B^2) + aZ_3$

$Y_2 \leftarrow (X_3 + D)(AC + Z_3) + (Y_1 + X_1)Z_3^2$

Let $Z_3 \rightarrow 0$ then:

$A \leftarrow (Z_2 + E)X_2 + Z_2^2 + UB \leftarrow X_2 + X_1 X_2$

$C \leftarrow BZ_2 C \leftarrow BZ_2 C^2 \leftarrow 1$(Neglected)

$D \leftarrow X_1 Z_3 \qquad E \leftarrow UX_1 \qquad X_2 \leftarrow U^2 + E + aZ_2$

$X_3 \leftarrow A^2 + C(A + B^2) + a$

$Y_2 \leftarrow (X_3 + D)(AC + 1) + (Y_1 + X_1)$

III. Proposed Algorithms

This paper aims to propose a new quintupling point 5P over general binary curve (short Weierstrass curve) which is given by (1) using LD coordinate. Two forms can be used to formulate the quintupling point 5P, which are $5P = 3P + 2P$ and $5P = 2(2P) + P$. For both cases, point doubling and point addition are required. For point doubling, the minimal form is as mentioned in Algorithm 5. While for point addition, a mixed addition formula using the affine and LD coordinate proposed in Algorithm 3 is usually deployed since the mixed addition is much faster [17].

The first quintupling point formula will be introduced using the formula $5P = 3P + 2P$, which require three operations, point tripling with mixed addition to point doubling. According to [12], the lowest tripling point 3P cost is the formula given in Algorithm 6. The proposed 5P formula is as presented in Algorithm 7.

Algorithm 7: New point quintupling of the form $5\mathrm{P} = 3\mathrm{P} + 2\mathrm{P}$ for general binary curve using LD coordinate.

Let $\mathrm{P} = (\mathrm{X}, \mathrm{Y}, \mathrm{Z})$ be a point on the curve $y^2 + xy = x^3 + ax^2 + b$ on the LD coordinate system, then the point $2\mathrm{P} = (\mathrm{X}_2, \mathrm{Y}_2, \mathrm{Z}_2)$ and $3\mathrm{P} = (\mathrm{X}_3, \mathrm{Y}_3, \mathrm{Z}_3)$. The 5P formula is given as:

The point $2\mathrm{P} = (\mathrm{X}_2, \mathrm{Y}_2, \mathrm{Z}_2)$ is the doubling for $\mathrm{P} = (\mathrm{X}_1, \mathrm{Y}_1, \mathrm{Z}_1)$ where:

$S \leftarrow X_1^2 \quad U \leftarrow S + Y_1 \qquad T \leftarrow X_1 Z_1$

$R \leftarrow UT \; Z_2 \leftarrow T^2 \qquad X_2 \leftarrow U^2 + R + aZ_2$

$Y_2 \leftarrow (Z_2 + R)X_2 + S^2 Z_2$

The point $3\mathrm{P} = (\mathrm{X}_3, \mathrm{Y}_3, \mathrm{Z}_3)$ is tripling for $\mathrm{P} = (\mathrm{X}_1, \mathrm{Y}_1, \mathrm{Z}_1)$ where:

$A \leftarrow (Z_2 + E)X_2 + Z_2^2 + UB \leftarrow X_2 + X_1 X_2$

$C \leftarrow BZ_2 C \leftarrow BZ_2 Z_3 \leftarrow C^2 \qquad D \leftarrow X_1 Z_3$

$E \leftarrow UX_1 \qquad X_2 \leftarrow U^2 + E + aZ_2$

$X_3 \leftarrow A^2 + C(A + B^2) + aZ_3$

$Y_2 \leftarrow (X_3 + D)(AC + Z_3) + (Y_1 + X_1)Z_3^2$

Let $Z_3 \rightarrow 0$ then:

$A \leftarrow (Z_2 + E)X_2 + Z_2^2 + UB \leftarrow X_2 + X_1 X_2$

$C \leftarrow BZ_2 C \leftarrow BZ_2 D \leftarrow X_1 Z_3$

$E \leftarrow UX_1 \qquad X_2 \leftarrow U^2 + E + aZ_2$

$X_3 \leftarrow A^2 + C(A + B^2) + a$

$Y_2 \leftarrow (X_3 + D)(AC + 1) + (Y_1 + X_1)$

The Point $5\mathrm{P} = 3\mathrm{P} + 2\mathrm{P}$ is equivalent to the form $(\mathrm{X}_5, \mathrm{Y}_5, \mathrm{Z}_5) = (\mathrm{X}_3, \mathrm{Y}_3, 1) + (\mathrm{X}_2, \mathrm{Y}_2, \mathrm{Z}_2)$ using mixed addition:

$G \leftarrow Y_2 + Y_3 Z_2^2 \quad H \leftarrow X_2 + X_3 Z_2$

$K \leftarrow HZ_2 \qquad Z_5 \leftarrow K^2 \qquad M \leftarrow X_3 Z_5$

$X_5 \leftarrow G^2 + K(G + H^2) + aK$

$Y_5 \leftarrow (M + X_5)(GK + Z_5) + (Y_1 + X_1)Z_5^2$

By counting the number of multiplication and squaring, the total cost of the formula 5P is $23M + 13S$. This new point will be proven as valid using the approach [13] and [18] provided in Lemma 1.

Lemma 1: The proposed point 5P of form $5P = 3P + 2P$ is valid.

Proof:

Affine coordinate is used to prove the formula. Adding two points in affine coordinate $(\mathrm{X}_5, \mathrm{Y}_5, \mathrm{Z}_5) = (\mathrm{X}_3, \mathrm{Y}_3, \mathrm{Z}_3) + (\mathrm{X}_2, \mathrm{Y}_2, \mathrm{Z}_2)$ should satisfy the equations:

$$\lambda = {(y_3 + y_2)}/{(x_3 + x_2)}$$

$$x_5 = \lambda^2 + \lambda + x_3 + x_2 + a$$

$$y_5 = \lambda(x_3 + x_5) + x_5 + y_3$$

Using Algorithm 7, it needs to be proven that $\frac{\mathrm{X}_5}{\mathrm{Z}_5} = \mathrm{x}_5$ and $\frac{\mathrm{Y}_5}{\mathrm{Z}_5^2} = \mathrm{y}_5$, the process is:

$$\frac{\mathrm{X}_5}{\mathrm{Z}_5} = \frac{\mathrm{G}^2 + \mathrm{K}(\mathrm{G} + \mathrm{H}^2) + a\mathrm{Z}_5}{\mathrm{K}^2} = \frac{\mathrm{G}^2}{\mathrm{K}^2} + \frac{\mathrm{G}}{\mathrm{K}} + \frac{\mathrm{H}^2}{\mathrm{K}} + \mathrm{a}$$

$$= \frac{[\mathrm{Y}_2 + \mathrm{Y}_3 \mathrm{Z}_2^2]^2}{(\mathrm{X}_2 + \mathrm{X}_3 \mathrm{Z}_2)^2 \, \mathrm{Z}_2^2} + \frac{\mathrm{Y}_2 + \mathrm{Y}_3 \mathrm{Z}_2^2}{(\mathrm{X}_2 + \mathrm{X}_3 \mathrm{Z}_2)\mathrm{Z}_2} + \frac{(\mathrm{X}_2 + \mathrm{X}_3 \mathrm{Z}_2)^2}{(\mathrm{X}_2 + \mathrm{X}_3 \mathrm{Z}_2)\mathrm{Z}_2} + \mathrm{a}$$

Let $Z_3 = 1$

$$= \left[\frac{Y_2/Z_2^2 + Y_3}{X_2/Z_2 + X_3}\right]^2 + \left[\frac{Y_2/Z_2^2 + Y_3}{X_2/Z_2 + X_3}\right] + \frac{X_2}{Z_2} + X_3 + a$$

$$= \left[\frac{y_3 + y_2}{x_3 + x_2}\right]^2 + \frac{y_3 + y_2}{x_3 + x_2} + x_2 + x_3 + a$$

$$x_5 = \lambda^2 + \lambda + x_3 + x_2 + a$$

$$\frac{Y_5}{Z_5^2} = \frac{(M+X_5)(GK+Z_5)+(Y_1+X_1)Z_5^2}{K^4}$$

$$= \frac{GK(X_3Z_5 + X_5) + Z_5(Y_3Z_5 + X_5)}{K^4}$$

$$= \frac{(Y_2 + Y_3Z_2^2)(X_3Z_5 + X_5)}{K^3} + \frac{X_5}{K^2} + Y_3$$

$$= \frac{(Y_2/Z_2^2 + Y_3)(X_3 + X_5/Z_5)}{(X_2/Z_2 + X_3)} + \frac{X_5}{Z_5} + Y_3$$

$$= \left(\frac{Y_2/Z_2^2 + Y_3}{X_2/Z_2 + X_3}\right)\left(X_3 + X_5/Z_5\right) + \frac{X_5}{Z_5} + Y_3$$

$$= \left(\frac{y_3 + y_2}{x_3 + x_2}\right)(x_3 + x_5) + x_5 + y_3$$

$y_5 = \lambda(x_3 + x_5) + x_5 + y_3$ (Proven)

While the second quintupling formula will use the form of $5P = 2(2P) + P$, which requires three algebraic operations, i.e. two doubling and one addition, the new formula is as presented in Algorithm 8.

Algorithm 8: New Point Quintupling of the Form $5P = 2(2P) + P$ for General Binary Curve Using LD Coordinate.

Let $P = (X, Y, Z)$ be a point on the curve $y^2 + xy = x^3 + ax^2 + b$ on the LD coordinate system, then the point $2P = (X_2, Y_2, Z_2)$ and $4P = (X_4, Y_4, Z_4)$. The 5P formula is given as:

The point $2P = (X_2, Y_2, Z_2)$ is doubling for $P = (X_1, Y_1, Z_1)$ where:

$S \leftarrow X_1^2$ $U \leftarrow S + Y_1$ $T \leftarrow X_1Z_1$

$R \leftarrow UT$ $Z_2 \leftarrow T^2$ $X_2 \leftarrow U^2 + R + aZ_2$

$Y_2 \leftarrow (Z_2 + R)X_2 + S^2Z_2$

The point $4P = (X_4, Y_4, Z_4)$ is doubling for $2P = (X_2, Y_2, Z_2)$ where:

$S_1 \leftarrow X_2^2$ $U_1 \leftarrow S_1 + Y_2$ $T_1 \leftarrow X_2Z_2$

$R_1 \leftarrow U_1T_1$ $Z_4 \leftarrow T_1^2$ $X_4 \leftarrow U_1^2 + R_1 + aZ_4$

$Y_4 \leftarrow (Z_4 + R_1)X_4 + S_1^2Z_4$

Let $Z_3 \rightarrow 0$, then:

$S_1 \leftarrow X_1^2$ $U_1 \leftarrow S_1 + Y_2$ $T_1 \leftarrow X_2Z_2$

$R_1 \leftarrow U_1T_1$ $T_1^2 \leftarrow 1$ (Neglected)

$X_4 \leftarrow U_1^2 + R_1 + a$

$Y_4 \leftarrow (1 + R_1)X_4 + S_1^2$

The Point $5P = 2(2P) + P$ is equivalent to the form $(X_5, Y_5, Z_5) = (X_4, Y_4, 1) + (X_1, Y_1, Z_1)$ using mixed addition:

$A \leftarrow Y_1 + Y_4Z_1^2$ $B \leftarrow X_1 + X_4Z_1$

$C \leftarrow BZ_1$ $Z_5 \leftarrow C^2$ $D \leftarrow X_4Z_5$

$X_5 \leftarrow A^2 + C(A + B^2) + aC$

$Y_5 \leftarrow (D + X_5)(CA + Z_5) + (Y_4 + X_4)Z_5^2$

By counting the number of multiplication and squaring in the previous formula, the total cost of the formula 5P is $17M + 12S$. As in the previous formula, the new point will be proven as valid as in Lemma 2.

Lemma 2: The proposed point 5P of form $5P = 2(2P) + P$ is valid.

Proof: Affine coordinate is used to prove the formula. Adding two points in affine coordinate $(X_5, Y_5, Z_5) = (X_4, Y_4, Z_4) + (X_1, Y_1, Z_1)$ should satisfy the equations:

$$\lambda = (y_4 + y_1)/(x_4 + x_{41})$$

$$x_5 = \lambda^2 + \lambda + x_4 + x_1 + a$$

$$y_5 = \lambda(x_4 + x_5) + x_5 + y_4$$

Using Algorithm 8, it needs to be proven that $\frac{X_5}{Z_5} = x_5$ and $\frac{Y_5}{Z_5^2} = y_5$, the process is:

$$\frac{X_5}{Z_5} = \frac{A^2+C(A+B^2)+aC}{C^2} = \frac{A^2}{C^2} + \frac{A}{C} + \frac{B^2}{C} + a$$

$$= \frac{[Y_1 + Y_4Z_1^2]^2}{(X_1 + X_4Z_1)^2 Z_1^2} + \frac{Y_1 + Y_4Z_1^2}{(X_1 + X_4Z_1)Z_1} + \frac{(X_1 + X_4Z_1)^2}{(X_1 + X_4Z_1)Z_1} + a$$

Let $Z_4 = 1$

$$= \left[\frac{Y_1/Z_1^2 + Y_4}{X_1/Z_1 + X_4}\right]^2 + \left[\frac{Y_1/Z_1^2 + Y_4}{X_1/Z_1 + X_4}\right] + \frac{X_1}{Z_1} + X_4 + a$$

$$= \left[\frac{y_4 + y_1}{x_4 + x_1}\right]^2 + \left[\frac{y_4 + y_1}{x_4 + x_1}\right] + x_1 + x_4 + a$$

$$x_5 = \lambda^2 + \lambda + x_4 + x_1 + a$$

$$\frac{Y_5}{Z_5^2} = \frac{(D+X_5)(CA+Z_5)+(Y_4+X_4)Z_5^2}{C^4}$$

$$= \frac{CA(X_4Z_5 + X_5) + Z_5(Y_4Z_5 + X_5)}{C^4}$$

$$= \frac{(Y_1 + Y_4Z_1^2)(X_4Z_5 + X_5)}{C^3} + \frac{X_5}{C^2} + Y_4$$

$$= \frac{(Y_{12}/Z_1^2 + Y_4)(X_4 + X_5/Z_5)}{(X_1/Z_1 + X_4)} + \frac{X_5}{Z_5} + Y_4$$

$$= \left(\frac{Y_1/Z_1^2 + Y_4}{X_1/Z_1 + X_4}\right)\left(X_4 + X_5/Z_5\right) + \frac{X_5}{Z_5} + Y_4$$

$$= \left(\frac{y_4 + y_1}{x_4 + x_1}\right)(x_4 + x_5) + x_5 + y_4$$

$y_5 = \lambda(x_4 + x_5) + x_5 + y_4$ (Proven)

The cost of the first formula where $5P = 3P + 2P$ is$23M + 13S$, while for the form $5P = 2(2)P + P$, the cost is$17M + 12$. The first formula has a high cost, since it uses four operations, for tripling we should doubling for the point then adding it to the point, i.e. $3P = 2P + P$then doubling the point P and finally adding them together, or $5P = 2P + P + 2P$, which means two doubling and two addition. While for the formula $5P = 2(2)P + P$, we have three operations, which are two doubling and one addition only. So, the preferred formula is $5P = 2(2)P + P$. The new point formula could not be compared to other point quintupling, since it is the first proposed point for the elliptic curve over binary curve using LD coordinates.

IV. Conclusion and Future works

Two new quintupling points are introduced over general binary curve using Lõpez-Dahab coordinate. Two formulas where used, $5P = 3P + 2P$ (Tripling adding to doubling) and $5P = 2(2)P + P$ (Doubling of doubling adding to point). The cost of the two formulas are $23M + 13S$ and $17M + 12S$ respectively. Therefore, the preferred formula is $5P = 2(2)P + P$ with lowest cost. Using mathematical proofing, these two points are proved as valid. This point can be implemented at scalar multiplication level using different scalar method. For example, for w-NAF method where $w \geq 4$, or with the precomputed quintupling point will save the time and memory at scalar multiplication level in ECC.

This point can be improved using different techniques and coordinate. A higher point also can be implemented such as point septupling 7P and nonupling 9P.

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YAWARweb: Pilot Study about the usage of a Web Service to Raise Awareness of Blood Donation Campaigns on University Campuses in Lima, Peru

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***Abstract*—This document presents a preliminary study about a pilot deployment of a web service. The service is used as means to raise awareness in university campuses prior to blood donation campaigns and to measure its effect into posterior donor enrollment. The measure the level of awareness a score range from zero to four inclusive was set. It was quantified before and after giving the information. This allowed evaluating the score change influenced by the received information. Another important metric was the contrast between the community participation between the blood donation campaigns at 12th June 2018 and June 2017. During these campaigns 41 and 25 blood units were collected following the new approach and the traditional way respectively. This variation represents an increase of 64% with respect to the campaign carried out in 2017 by INSN-SB, where the only variation was the use of the application YAWARweb. Moreover, in 2018 there were 36 people interested to donate. Nonetheless, it was not possible because of insufficient hemoglobin, narrow veins, and other causes. This research has as goal to evaluate the usage of our survey through a web service as a tool to raise awareness in university campuses prior to blood donation campaigns. This survey will provide information to the participants about the benefits of blood donation. Thus, creating an incentive to participate in the campaigns and getting the results as an increment of the number of participants. Our group keeps working on preventive health and changing the picture of blood donation leveraged by technology development. The document starts with a general summary of the situation of blood donation in Peru, and then it analyzes the population where the tool is applied. It then proceeds to the methodology of implementation of YAWARweb. Finally, it presents the results of the use of the web application in the community as a method of raising awareness.**

***Keywords*—Aplication; survey; blood donation; donor benefits**

I. Introduction

Serious patients with leukemia, severe anemia, affected by traumas or women in a critic state before or after giving birth (during pregnancy) need blood units for their treatment and health recovery [1]. That is why blood and its hemo-derivatives are required in health centers to prevent and treat complicated patient's status that may be lethal [2]. World Health Organization (WHO) recomends that 2% of the population of every country should donate blood in order to have enough supply during a emergency [3]. In Peru, the number of donors is lower than 0.5% according to the Hemotherapy National Program and Blood Bank (Programa Nacional de Hemoterapia y Bancos de Sangre, Pronahebas). This number becomes even more critical given that only 5% of it relates to voluntary donations, while 95% is by blood reposition [4].

Peru needs 600 thousand blood units to have enough supply for an emergency. By 2013 185 thousand units were collected. They represent 30.8% of what is required. In contrast with previous years, the number is increasing, yet it is not close to the target requirement.

This issue arises because donation campaigns do not reach enough people and those that volunteer are scarce. Peru has the lowest index in latinamerica (OPS-2015).

There are 333 Hemotherapy and blood banks in Peru.

There are mobile applications related to blood donation. From those that are present in Googleplay we have analyzed the top 10 with highest ratings finding some common features. In Fig. 1, we show the results of this analysis. They are oriented for donors inscription, sending an alert when they donate, search the nearest donation center, but in general, these applications aim for people that are already aware and are interested in donating blood, none of the applications is aimed at raising awareness. The target audience of our proposed tool YAWARweb are people at university campuses. The tool is anonymous to reduce rejection of participation, provides information about the requirements and personal and altruistic benefits of blood donation.

Our project works on preventive health, through a web service that provides an online survey. The tool is used by people responsible to raise awareness, university students or health personnel. Thus, the process becomes customized and gets a better participation response.

Normally prior to a blood donation campaign an awareness campaign is scheduled. It proposes the use of YAWARweb for the realization of personalized awareness based on the benefits and awareness of blood donation. In Fig. 2, it shows a photo of the awareness campaign with YAWARweb.

Nombre de aplicación	Tamaño	evaluación	num personas	requerimiento	version	instalaciones
dona sangre(Beta)	9.11	3	2	android 4.0.3	1.1.2	50+
Dale Vida Perú	4,8 M	4.3	9	android 5.0	1.1.4	100+
Dona Sangre Andalucia	4	3.3	175	android 4.0.3	1.0.2	10000+
Donante	755 K	4.1	22	android 2.3.3	2.1	500+
Donan de sangre de Euskadi	3.7	4.2	115	android 4.1	1.3.3	5000+
Dona +	6.7	4.6	10	android 4.4	0.0.6	100+
Donantes	485 kb	1.8	4	android 2.1	0.99 b	100+
Anmol blood donor search app	3,8 M	0	2	android 4.0.3	2	100+
Blood Friends - blood donate app	4,2 M	0	45	android 4.1	1.0	1000+

Fig. 1. Table of the Characteristics of Applications Similar to YAWARweb.

Fig. 2. Photograph of the Awareness Campaign using YAWARapp.

Our web service has been designed in such a way it is specific, sensitive, trustful and useful. This service will enable the assessment of potential blood donors and raise awareness prior to blood donation campaigns in university campuses.

II. Population and Sample

A. Sample

Data has been collected opportunistically at the campus of Universidad de Ciencias y Humanidades, by 11th June 2018, from 9:00am to midday. In total 114 people were approached.

It can describe from the approached people that the age range was between 18 to 50. We have divided this range into three. From 18 to 22, 22 to 30 and 30 to 50 representing the 78.07%, 9.65% and 12.28% of the population respectively. This is shown in the following Table I.

It is also important to analyze the gender distribution. It was 3% and 27% for the female and male participants respectively.

It is described in Table II.

TABLE I. Age Range of Participants

Age range			
Total Participants	***18-22***	***22-30***	***30-50***
114	89	11	14
100%	78.07%	9.65%	12.28%

TABLE II. Participants Gender Table

Gender of participants		
Total Participants	***Female***	***Male***
114	68	46
100%	59.65%	40.35%

III. Methodology

The developed tool YAWARweb, was done with php(v 5.2.19), apache(v 2.4.18) and Mysql (v 5.7.11).

The data base of the web service showed differentiated data identification to 1) determine if the participant is able for donation and 2) provide information about blood donation benefits. The following Fig. 3 describes the structure.

User identification is not enabled for survey participants. This identification is for personnel responsible of the raise of awareness (Fig. 4). The illness table is to identify those illnesses that exclude the participant as donor. Personal information data is optional in case the participant is willing to receive information about being a donor or campaign promoter.

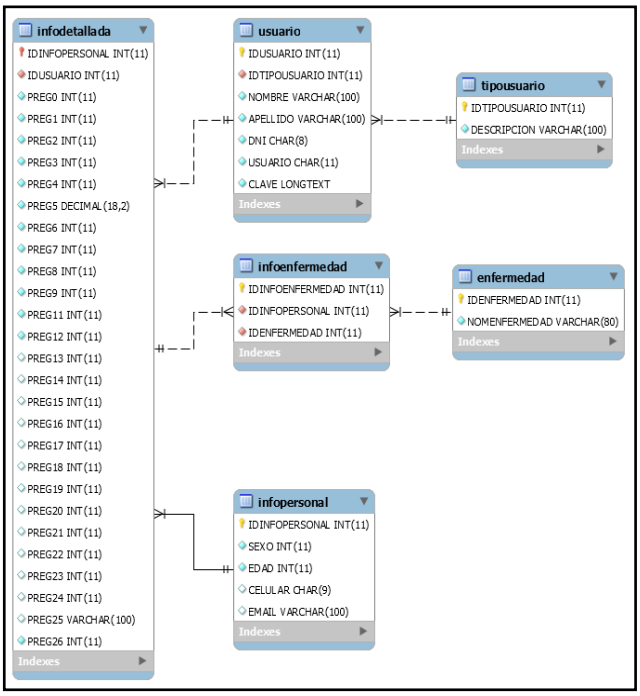

Fig. 3. Structure of the YAWARapp Information Tables.

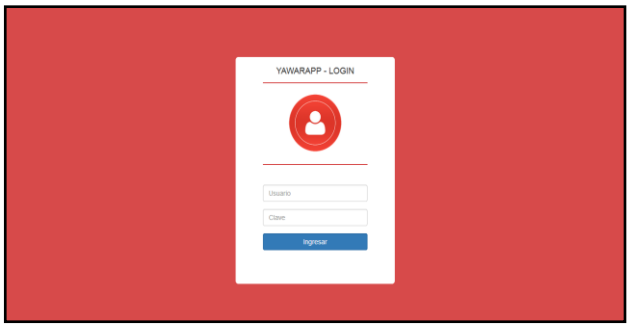

Fig. 4. Initial Web Screen of the YAWARweb Web Application.

Question groups are:

1) Initial appreciation of blood donation.

2) Questions to evaluate if the participant is able to be a donor.

3) Direct benefits of blood donation.

4) Benefited population by the blood donation.

5) Ask if it the participant wants to receive information about becoming a donor.

6) Lastly, evalute the appreciation of blood donation after acknowledging the benefits of blood donation.

This is a first study about the required data to design YAWAR web. Therefore this analysis is descriptive, explaining key findings and focusing on the overall characteristics from the population of university campuses and their point of view about blood donation. The survey was anonymous. Information collected was divided into three sections: First section- preferences and scoring of 23 statements on the benefits of donating blood; Second section- eligibility criteria for potential blood donation; Third section- participants' likelihood of donating bloods given the information provided on its benefits.

Questionnaires were disseminated by INTIlab team members to UCH and UPCH students studying nursing, accounting, administration, electrical engineering, biology, physics, and computer science.

The division of sections is detailed as follows:

First Section: Details were provided of 23 potential benefits so that participants could give a score between zero and four where zero is disagree and four is fully agree. In addition, every potential benefit was given in both a statement and a question from. Participants were asked to pick which format they preferred or alternatively they could reject the benefit altogether, it can display the home screen of the web application in Fig. 5.

The aforementioned benefits included examples of benefits for either the donor or the recipient of blood. Below are some examples of the benefits of blood donation that are given in the questionnaire:

- Serves a general health check.
- Thirteen blood analyses are undertaken on a sample of your blood for free [3].
- Reduces the number of cardiac arrests [4].
- Reduces blood viscosity [5].
- Reduces the amount of iron in blood.
- Rejuvenates the body [5].
- Benefits for regular blood donors.
- The amount of people that can be helped [3].
- Patient groups that benefit.

Fig. 5. Representation of Oblique TEC (sTEC) and Vertical TEC (vTEC).

Second Section: Twelve questions are asked relating to the individuals health and prior illnesses to help establish if they may be eligible for blood donation. These questions were based on the pre-donation forms used by Hospital Cayetano Heredia's blood bank, San Borja International Clinic, and the Peruvian Institute of Child Health.

Third section: At the beginning of the questionnaire participants are asked to score their willingness to donate blood and why they have chosen that score. In the third section at the end of the questionnaire this same question is asked again. This is done in order to evaluate if the information given on the potential benefits of blood donation have changed the participants willingness to donate. We have used this measure to initially evaluate if a tool such as YAWARweb that explains the benefits of blood donation could indeed improve blood donation rates on university campuses prior to donation campaigns. In addition, the third section has questions on participants' opinions on receiving text messages containing information on the benefits of blood donation.

The service used the university services and the Image Processing INTI-Lab Laboratory server.

The service also allows to see the received data in real time.

IV. Results and Conclusions

The questionnaire was designed in order to facilitate the collection of information regarding the public's opinions on blood donation. The goal is that this could be used as a tool for raising awareness prior to blood donation campaigns on university campuses. The amount of valid particiants for this study was 114.

The knowledge about the benefits of blood donation was evaluated. The following statements on the benefits of donation received the highest scores:

- Thirteen blood analyses are undertaken on a sample of your blood for free.
- Reduces the number of cardiac arrests [6].
- Reduces hepatic damages [7].
- Benefits as regular donors.
- Reduces diabetes risks [8].
- Patient groups that benefit.

Benefit	Frequency	Percentage
Donation as check-up, perform a blood count	51	44.74
Additional exams approximate cost $ 150	12	10.53
Reduces the likelihood of heart attack	13	11.4
Decreases damage to the liver	17	14.91
Decreases risk of diabetes	17	14.91
Twice a year to be a frequent donor	11	9.65
Blood is divided into blood products	40	35.09
of every 4 units needed there is only one available	25	21.93
Benefits pregnant women	34	29.82
Oncology patients	43	37.72
Surgery	51	44.74

Fig. 6. List of Benefits and Knowledge of each unop in the Participating Population.

We can observe in Fig. 6 that the less known statement, with only 9.65% of acknowledgement, is becoming a regular donor. Hence, by doning it is possible to receive blood analysis results within 10 to 15 days. These exams have a cost of USD 150.00 in private clinic laboratories in Peru. By donating the exams are free.

In the second questionaire group, about the willingness to become a donor, 83.33% of the participants have never donated blood. It is shown in the following Table III.

The last date of donation was also asked, it was found that only 2 from those that have previously donated have done it in the last 5 months before the survey (Table IV). This disable them to donate in the next campaign.

Among the participants, 51.75% and 48.25% were qualified as potential donors and disqualified respectively, as you can see in Fig. 7.

TABLE III. PREVIOUS DONOR PARTICIPATION TABLE

Previous donor		
Total Participants	*Donated before*	*Never donated*
114	19	95
100%	16.67%	83.33%

TABLE IV. LAST DONATION TABLE

Previous donor		
Total Participants	*Donation before 5 months*	*Donation in more than 5 months*
114	2	112
100%	1.75%	98.25%

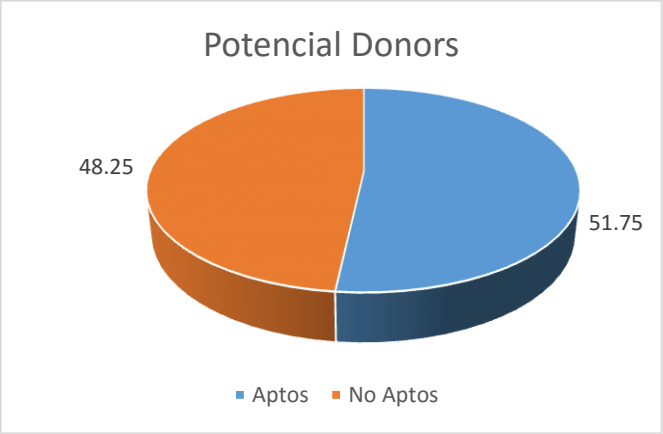

Fig. 7. Graph of the Number of Participants Eligible for Blood Donation whom Participated in the Awareness Campaign.

The third group of questions measures if acknowledging the donation benefits influenced the willingness to donate. The results show that 61.40%, 35.09% and 3.51% kept, raised and diminished their appreciation, respectively; this can be seen in Fig. 8 and Table V.

This is the first metric for the YAWARweb tool in benefit for raise awareness of participant prior to blood donation campaigns. Another metric to evaluate the efficiency of the campaign is to measure if the participation rate improved significantly. Therefore we have the following chart:

TABLE V. AWARENESS ANALYSIS

Valorization of blood donation			
Total Participants	*Kept their valorization*	*Raised their valorization*	*Diminished their valorization*
114	70	40	4
100%	61.40%	35.09%	3.51%

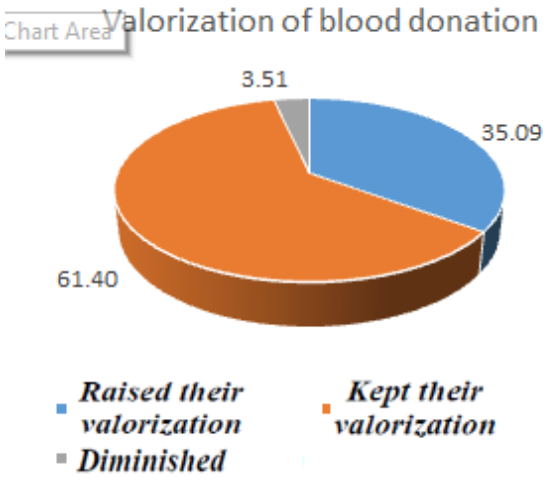

Fig. 8. Percentage of Participants who Increased their Assessment Since Yawarweb.

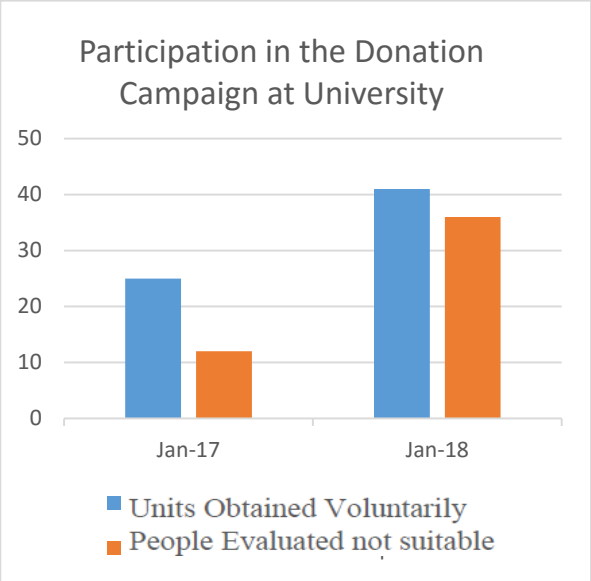

Fig. 9. Variation of Participation in the Blood Donation Campaign, Yawarweb was used in the Awareness Campaign in 2018.

In Fig. 9, it can visualize the effect of using YAWARweb as part of the awareness campaign, where a 64% increase has been found in comparison with a previous campaign. In addition, 40 people that received the intervention, one day before the campaign of June 12th, arrived with a great interest of participation.

As a consequence of the analysis of the pilot usage of the web service as part of a prior awareness stage before a blood campaign we can conclude:

1) With YAWARweb, the knowledge of people from the university campuses about the benefits and destination of blood donation was evaluated. This measurement was performed as described in Table III.

2) The most known statement in the survey was relate to the initial hemogram in a donation procedure. It was known by the 44.74% of the participants. The least known statement was about the role of a regular donor that provides the Blood Bank from Cayetano Heredia Hospital. It was ignored by 90.35% of the participants. Moreover, the benefits as renewal of the blood torrent as a result of the donation was also ignored. It was surprising that 64.91% of the participants ignored that blood was divided into hemo-components and as consequence one person was not benefit but three. Because blood is divided into red blood cells, plasma and platelets. Also considering the fact that the blood sample goes under 13 tests at least.

3) The following Table VI shows how many people did not know the benefits present on each statement.

4) Participants are more likely to participate in this kind of awareness campaign because it is customized. Most of them had questions about the information that was provided and their interest to keep receiving information to become a donor or donation promoter. This fact is remarkable. The amount of participants willing to receive information are shown in the following Table VII.

TABLE VI. AMOUNT OF KNOWLEDGE OF THE BENEFITS

Benefit	People that did not know	Percentage
Donation as a health check, hemogram analysis.	63	55.26
Additional tests valued on USD 150 approximately	102	89.47
Reduces risks of a heart attack	101	88.60
Reduces liver damages	97	85.09
Reduces diabetes risk	97	85.09
If donates twice a year becomes regular donor	103	90.35
Blood is devided into three components (Hemo-derivatives)	74	64.91
Only one of 4 required units is available	89	78.07
Benefits pregnant women	80	70.18
Benefits oncological patients	71	62.28
Benefits patients of surgery, traumas, anemias, etc	63	55.26

TABLE VII. PEOPLE INTERESTED IN PARTICIPATE

Condition	Frequency	Percentage
Donor	53	46.49
Promoter	13	11.40
Not interested	12	10.53
Donor and Promoter	25	21.93
Left empty	11	9.65
TOTAL	**114**	**100**

From the participants, 46.49%, 11.40%, 21.93% and ~20% were interested in receiving information to become a donor, promoter, donor and promoter and not interested or left empty this section, respectively. Those interested in becoming a promoter were aware they require additional training.

5) The raise of awareness one day before a campaign is effective. There was a significant increment of 64% of participation during this blood donation campaign performed by the UC of INSNSB.

6) It is important to provide options to people interested in donation but unabled to do it. An example is to encourage the rol of promoters.

7) The training to the support personnel was done in one hour. Solving doubts and teaching them how to use the online service. The service has been shown to be usable and easy to use by people interested in the process.

The objective of this study was to use all the described items in order to demonstrate that the usage of this tool to raise awareness on the topic of blood donation is valid and thus, increase the participation rates.

The obtained results will facilitate the next phase of our study with a better understanding of the target population from university campuses.

An asynchronous application will be implemented in a next stage of research, in order to massify the use of YAWARweb by the blood banks of Lima, as part of the awareness campaigns, this will allow an increase in participation in donation campaigns, through a free and simple tool.

The advantages of using YAWARweb is the reproducibility of the information delivered properly concentrated and prepared by specialists at low cost, the fact of having correct information allows to reduce the barriers in the population for blood donation, the delivery of personalized information supports to the awareness of the university students in the requirements to the population that is benefited with their donation, the registration of the data and the synchronization of the same for epidemiological analysis that will allow a detailed study of the population in which the Blood donation campaigns, and massification, will allow us to carry out more rigorous analyzes of diseases by communities, risk behaviors, or predisposition for promoters or potential donors.

We would like to thank UCH for their support in the development of the questionnaires and for providing financial support to the initial phase of this proof of concept of the project YAWARweb. In addition, we would also like to thank the Blood Bank for the information they have provided us and guidance to use the questionnaire as a tool for increase awareness in population prior to blood donation campaigns on university campuses. Finally, thank the Blood Bank of the Instituto Nacional de Salud del Niño de San Borja for allowing us to use the tool in the blood donation campaign as an alternative tool to raise awareness.

We keep working on preventive health and to diminish health gaps all over our country.

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Transforming Service Delivery with TOGAF and Archimate in a Government Agency in Peru

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***Abstract*—The application of The Open Group Architecture Framework (TOGAF) and Archimate to transform the citizen's service delivery by the Ministry of Labor and Employment Promotion of Peru is presented. The enterprise architecture development has followed the phases of the TOGAF Architecture Development Method (ADM) method: Architecture Vision, Business, Data, Application and Technology Architecture Definition to determine the source architecture, the target architecture and gaps to meeting the target architecture requirements. The strategic motivations, active structure, passive structure, behavior and different viewpoints models in the domains: business, data, application and technology have been constructed with the Archimate descriptive language. The viewpoints achieved by the conjunction of these open standards have allowed identifying fragmented and isolated business services, as well as duplicated data and duplicating application functions. A proposal for integrated and transversal services emerges as a result of the applied Enterprise Architecture approach. Design science is applied to obtain knowledge from the generated artifacts. The knowledge generated from this application can be useful for new initiatives to improve the delivery of services to the citizen in the Peruvian government.**

***Keywords*—Enterprise architecture; business architecture; digital government; The Open Group Architecture Framework (TOGAF); archimate; design science**

I. Introduction

In 2016, the Organization for Economic and Co-operation and Development (OECD) elaborate the "OECD Public Governance Reviews: Peru-Integrated Governance for Inclusive Growth" [1] where it recommends that Peru should follow a comprehensive reform agenda of the public administration, which consists in taking advantage of digital government to achieve open and transparent government capacities, in order to strengthen the making decisions, reducing costs and improving the quality of citizens services.

Despite the advances, the diagnosis that the OECD delivers to Peru revolves around its current approach that limits the achievement of strategies and integration: "the consequence of adopting a procedural, legalistic and technical approach to digital technology may be undermining the achievement of more strategic and integrated results while the government carries out its modernization efforts in this area "[1].

An Enterprise Architecture (EA) provides an understandable representation of the structure and strategic motivation of a purposeful activity, both in an organization or in a transversal functional area [2]. An EA is an essential tool to effectively and efficiently design business and missional processes and to implement and evolve information systems. There are 67% of countries in the world in the process of developing their EA or similar program to improve interoperability around public administration information systems, mitigate duplicate information, and maximize return on investment [3].

In Peru, as part of responding to the recommendations of the OECD regarding improving its digital government capabilities, the Digital Government Law has been enacted [3], whose main objective is achieve cross-cutting citizen's services with the intensive use of digital technology in government agencies.

Many countries encourage their government agencies and local governments to introduce enterprise architecture approach, developing principles, standards, frameworks, and reference models. Meanwhile, other more advanced countries have made the effort to develop a government-wide enterprise architecture [4] which is encouraged to provide a comprehensive view of enterprise architecture to their agencies [5]. This is the case of: Federal Enterprise Architecture (FEAF) [6], Australian Government Architecture (AGA) [7], United Kingdom cross-Government Enterprise Architecture (xGEA) [8], Singapore Government Enterprise Architecture (SGEA) [9], Korea Government-wide Enterprise Architecture (GEA) [4]. India Enterprise Architecture (IndEA) [10], Business Architecture Reference Framework (AE) for IT Management in Colombia [11] and others. In Peru, a government-wide architecture framework has not yet been stablished, and there is still no clear guidance on how achieve it, which is difficult due to the fact that there is not a CIO body of government with competences in Enterprise Architecture.

In the world, there are initiatives to apply enterprise architecture at a sector level, that is, in a government agency and in local governments; e.g. U.S. Office of Personal Management with the establishment of the Human Resources Line of Business (HR LOB) [12], HR LOB has used enterprise architecture to drive the transformation towards a new Human Resources service delivery model by crossing the US federal government in 2004.

The current initiative of the Ministry of Labor and Employment Promotion of Peru, regarding the development of its enterprise architecture, is motivated by: 1) Reduce the complexity of information systems by ensuring alignment with strategic institutional motivations, redesign and delivery of transversal services to the citizen, uniformed applications and standardized data (without duplication), virtualization consolidated and distributed, technological support for

interoperability, scalability and take advantage of the elasticity of the Cloud. 2) Reduce information systems maintenance costs and; 3) Manage efficiently institutional and technological change.

The research methodology used in this work is Design Science, as proposed in [13]. The next section presents the related work on applying TOGAF and ARCHIMATE to transform the delivery of services in the public sector. Design science is applied, to obtain knowledge of the constructed artifacts of the definition of enterprise architecture in the Peruvian labor agency, with its corresponding demonstration and evaluation. The knowledge generated in this work can serve as lessons learned to support new and next similar initiatives.

II. Related Work

The implementation of enterprise architecture in the health sector of Norway, indicates that when the roles of enterprise architecture are not established, there is not effective communication, there is weak commitment and maturity with EA and there is difficult to use EA tools, all this can impede the process towards the achievement and adoption of an EA common [14].

Government agencies typically have different structures and business areas / services that often lead to duplicate information systems and fragmented business processes and services, reducing the possibility of cross-agency interoperability [14]. Therefore, governments pursue EA initiatives, in addition to the aforementioned general EA benefits, to enable their business processes to be carried out from start to finish, across all government agencies, to increase online services [15] to provide new tools to manage business; and IT alignment with agencies for better integration of technologies, to rationalize data and application structure and to provide business modularity[16].

Another application of EA in the public sectors of labor and welfare, hospital and health of Norway concludes that autonomy, financial matters and the understanding of EA, are the three most important aspects to address success with EA in the public sector [17].

There are few examples of practical use with architecture development frameworks, modeling of designed artifacts and the reasonableness to identify architectural gaps [18]. Few works present the rationality of a regular application of enterprise architecture to a government agency to verify the benefits of simplification and change management that theoretically offers.

As mentioned in the introduction, the research methodology used in this work is Design Science Research Method (DSRM) where a research proposal is developed and validated to solve a problem [13]. This methodology is an iterative research process (as Table I shows) with the goal of overcoming standard research methodologies, such as traditional descriptive research and interpretive research, whose research outputs are largely explanatory and often not applicable to problem solving in practice [18]. DSRM covers this gap with design and creation of an applicable solution explicit to a problem, being an accepted research paradigm in the engineering area.

TABLE I. Design Science Research Methodology

Phase	***Description***
Define the problem and motivation	Define problem and show the importance
Define objectives of a solution	What would a better artifact to accomplish?
Design and development	Artifact
Demonstration	Find suitable context, use artifact to solve problem
Evaluation	Observe how effective and efficient, Iterate back to design
Communication	Scholarly publications, professional publications

Archimate delivers a uniform representation of EA models and views, offers an integrated architecture approach that describes and visualizes all architectural domains, their relationships and dependencies delivering different viewpoints for selected stakeholders, as well as support being extended.

III. Problem Definition

Currently, Ministry of Labor and Employment Promotion of Peru maintains 105 applications and a data center with 37 physical servers and 66 virtual servers. The agency has two business divisions: regulatory labor and employment promotion. In front of the need for information, the entity generates mechanisms and rules to collect information from working citizens. This can be through a service (worker formalization, labor intermediation, employer registration, job offer registration, etc.) or through a regulatory obligation (registration of a civil construction worker, etc.). Due to a defragmentation of efforts, news applications are developed for the news initiatives of each business division. As a result, there is a duplication of information, repetition of the same functionality in different applications, complex and disaggregated services to the citizen.

There is no shared representation of this reality, which allows identifying the problematic situation in a standard language for all stakeholders and with well-defined concepts to achieve common understanding of the problem and proposed solutions. There is no architectural development method that enables capacities for the diagnosis of gaps, establishment of a desired architecture, refinement of solutions and opportunities, a migration plan and the governance of the same in the aforementioned government entity.

IV. Proposed Solution

The objective of the proposed solution under the enterprise architecture approach in the aforementioned government entity is: 1) Ensure alignment between strategic motivators and business processes and services. 2) Ensure alignment between citizen's services and business processes with applications, data and technological infrastructure underlying. 3) Achieve and contribute to redesign the citizen's cross-cutting services and simplify, standardize and interoperate the corresponding data, applications and technological infrastructure.

V. TOGAF, ARCHIMATE AND VIEWPOINTS

To achieve the objective of the proposed solution, it was required to carry out the phases of the TOGAF ADM, the initial evaluation of architectural capabilities, the architecture vision and principles, the business, data, application and infrastructure architecture definition. This phase allows identify opportunities and candidate solutions as effective responses to architecture requirements and gaps. At present work, the resulting viewpoints modeled with Archimate are presented with its rationality, to justify the paper proposed solutions.

The most significant viewpoints are presented with a top-down approach from the strategic motivations towards the architecture of information systems.

A. Motivational Viewpoint

The stakeholders that correspond to the two business divisions are identified: Labor regulation and employment promotion, whose motivators are the formalization of employment as well as strengthening the accessibility to work certificate. The goals to achieve are to increase the formal employment rate and the opportunities for the insertion of young workers. The requirements to achieve this are the workers' register and the unique work certificate for young workers. The principle of enterprise architecture is to maximize the benefit of the government agency as a whole, limited by the budget for results. Fig. 1 displays the motivational reality modelling as has been described.

B. Strategies Viewpoint

The courses of action are to promote the formalization of work as well as the employability of young workers through technical assistance and official certification of competencies, with the use of normative, supervisory and national employment centers. Showing the resources allocated to provide said capabilities. Fig. 2 presents the strategic reality modelling saving to match.

C. Business Process Cooperation Viewpoint- AS IS

The civil construction worker registration business service is presented in Fig. 3. Although pursue different strategies and satisfy the interests of different stakeholders, both services realizing common activities such as register a worker, and after a sequence of information validations. They deliver a printed certificate, upon completing the process flow.

At this point, two citizen's services (the second service is not presented due to space), which follow separate activities flows have been identified. In order to define the desired business architecture, it is necessary to make use of the architectural principles, which indicate "Establish cross-sectional citizen's services integrating organizational units and business processes". Under that reasonableness the desired business architecture is designed, with a single worker registration process, and as part of the flow there is a procedure to typify the worker and capture the corresponding information, the flow ends with the issuance of a standardized record and with 100% digital technologies.

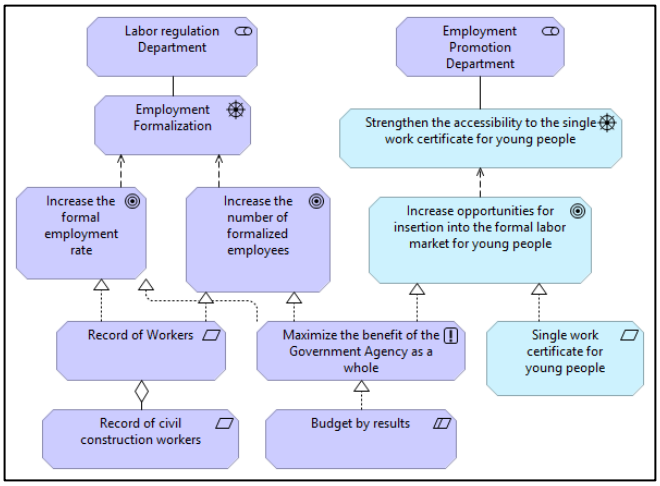

Fig. 1. Archimate Motivational Viewpoint.

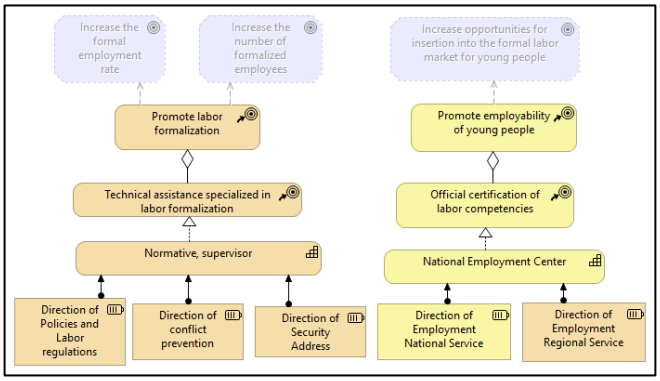

Fig. 2. Archimate Strategy Viewpoint.

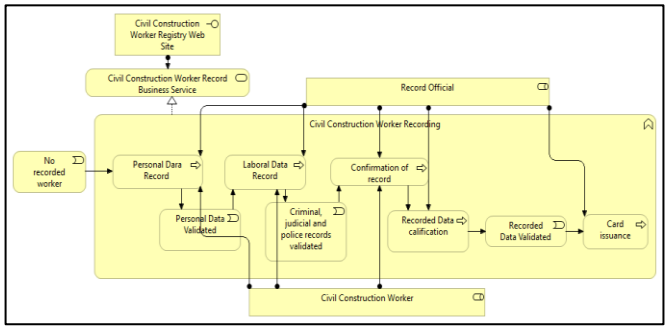

Fig. 3. Archimate Civil Construction Worker Recording Business Process Cooperation Viewpoint.

D. Business Process Cooperation Viewpoint - TO BE

Consider the standardization of the delivery of the transversal citizen´s service. That is, the simplification of worker registration services. The new redesigned citizen's service is presented in Fig. 4. The process of worker registration is only one, and there is a new registration typing process where will get customizing information about worker such as required to business rules. The information validation process is centralized to abstract this rules for doing easy the reutilization and maintainability.

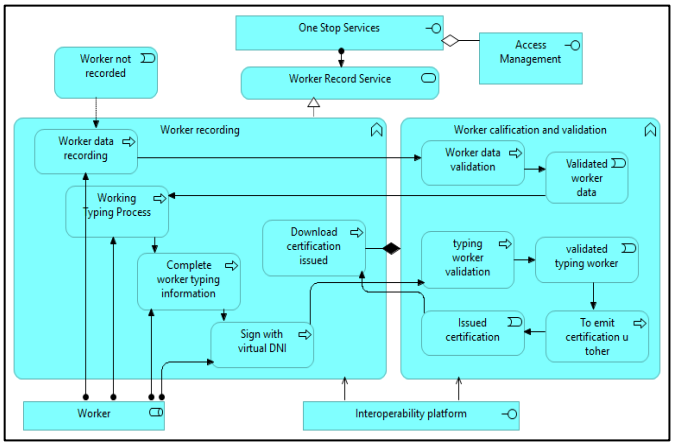

Fig. 4. Archimate TO BE Worker Recording Business Process Cooperation Viewpoint.

E. Application Cooperation Viewpoint - AS IS

It is appreciated that the current applications that support are duplicated at the level of application functionalities and redundant information but overall no standardized software component and libraries, such as Fig. 5 shows.

F. Application Cooperation Viewpoint - TO BE

From the Archimate representation, common components and standards for simplify the applications and removed duplicated functionality and redundant information has been identified. This will satisfy requirements for standardization, interoperability, scalability, security, orientation to services as well as functional. It consists of identifying components of common use and reusable as well as an exploration of solutions in the industry. The decoupling of the components facilitates maintenance as well as the most effective team work. The TO BE application cooperation replaces all the worker registration systems of the aforementioned government agency: civil construction worker registration, foreign worker's registration, SME worker registration, etc. Offering a cross-sectional worker registration service that can cross all public agencies in the medium term. Fig. 6 shows TO BE application cooperation viewpoint on Archimate language.

Table II shows the gap analysis developed after the realization of definition source architecture and target architecture. In this table, are presented the architecture requirements and your respective candidate solutions. All they save relation with the Archimate model presented.

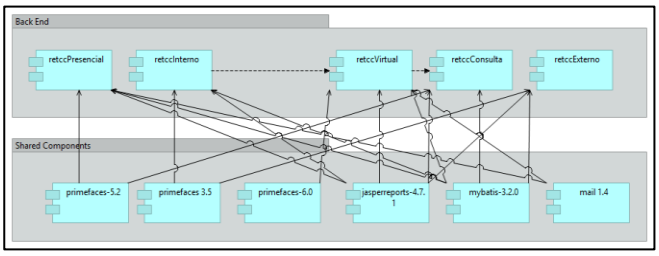

Fig. 5. Archimate AS IS Worker Recording Application Cooperation Viewpoint.

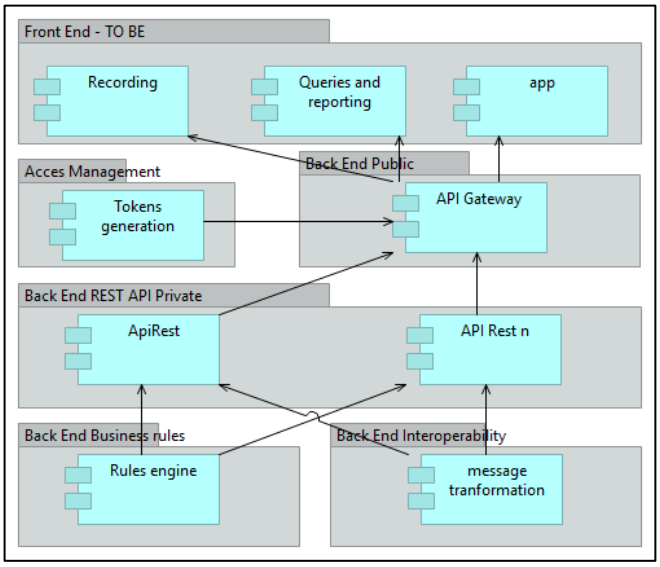

Fig. 6. Archimate TO BE Worker Recording Application Cooperation Viewpoint.

TABLE II. ARCHITECTURE GAP ANALYSIS

		Target Architecture (TO BE)		
		Worker Cross Registration	Rules Engine Component	Removed
Source Architecture (AS IS)	C.C. Worker Registration	Migrate		Remove in medium term
	CC Data Calification		Migrate	Remove in medium term
	New	Transversal capacity of worker registration	Ability to update and reuse business rules throughout the processes	

VI. DEMONSTRATION AND EVALUATION

As a result of the model developed with Archimate realizing TOGAF ADM exercise, the usefulness of Archimate viewpoints and artifacts has been demonstrated to generate value for the aforementioned government agency, such as designing cross-sectional services for citizens. The evaluation of the proposal to confirm its added value is executed through the method used to map quality characteristics. Bunge-Wand-Weber method [19] is used to allows the mapping of following attributes of the Archimate model: Incompleteness, redundancy, excess and overload. Also, Moody and Shanks framework [20] is used to manage the quality of the model in: completeness, integrity, flexibility, understanding, correctness, simplicity, integration and implementability. The resulting evaluation is that the Archimate views presented are qualitatively satisfactory.

VII. Conclusions and Future Work

With the joint application of TOGAF and Archimate, the objectives pursued by the solution proposal have been met: 1) Ensure alignment between strategic motivators and business processes and services, 2) Ensure alignment between processes and services of business with the applications and data, 3) Achieve and contribute to redesign citizen´s cross-cutting services, standardize and make interoperable the corresponding information systems. The exposed knowledge can serve as a base to support new similar initiatives in the framework of better services to the citizen in the Peruvian state.

Acknowledgment

Thanks to the General Office of Statistics and Information Technology and Communications (OGETIC) of the Ministry of Labor and Employment Promotion of Peru for having an opening to develop a complete exercise of enterprise architecture development and as a result this article has been achieved.

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Let's Code: A Kid-friendly Interactive Application Designed to Teach Arabic-speaking Children Text-based Programming

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***Abstract*—Programming is the cornerstone for the development of all of the technologies we encounter in our daily lives. It also plays an important role in enhancing creativity, problem-solving, and logical thinking. Due to the importance of programming in combination with the shortage of Arabic content that aims to teach children programming, we decided to develop *Let's Code*, an interactive mobile-based application designed for Arabic-speaking children from 8 to 12 years old. The application focuses on the basics of programming such as data types, variables, and control structures using the Python programming language through a simple, attractive, and age-appropriate design. The application presents its users with an interesting storyline that involves a trip to space with "*Labeeb*", a robot character designed to explain programming concepts to the child throughout the trip. Each planet represents a level in the application and introduces a programming concept through a set of lessons and exercises. The application can be used by educational institutions and parents to teach programming and will provide an opportunity through which Arabic-speaking children can keep up with the development and dissemination of technology.**

***Keywords*—Edutainment; mobile application; interactive application; Arabic; children; programming; coding for kids; Python**

I. Introduction

Programming skills are becoming increasingly important in our digital era. In recent years, many programming education initiatives have arisen in Arab countries. In December 2017, the MiSK foundation launched "Saudi Codes," an initiative encouraging Saudi students to learn coding skills and participate in programming culture [1]. In October 2017, Mohammed bin Rashid Global Initiatives (MBRGI) launched a huge initiative to teach programming called "One Million Arab Coders." The program aims to empower one million Arabs with different programming skills via free online courses [2]. These initiatives, both of which are sponsored by governments, are positive signs of the increased recognition of the importance of programming in the Arab world. However, it is important to recognize that any attempt to build a new generation with good programming skills and technological abilities must start with children.

Learning how to code can help children enhance their creativity, logical thinking, and problem-solving skills that can be applied in both their personal and professional lives. Liao and Bright found that programming increases brain abilities involved in learning and progress [3]; in their study, students with experience in the field of programming achieved 16% higher on cognitive ability tests than students who did not have programming experience.

On this basis, we built an edutainment application that aims to teach Arab children the basics of Python, which is a simple object-oriented programing language. We chose Python because of its ease of use; Python is designed to be more readable and easier to understand than any other scripting language. Python scripts are one-third to one-fifth the size of the equivalent code in C++ or Java [4]. We considered that using Arabic as the primary language in the application would help Arab children understand programming concepts without having to additionally learn the terminology in a foreign language.

In this project, we hope to help Arab children take a step beyond their unproductive use of the Internet by teaching them programming, one of the most powerful and essential tools for digital productivity. We aim to develop their "Digital Fluency": the ability to design, create, and invent with new media [5], which is far more than the activities in which children are currently engaged such as texting, playing, browsing, and interacting online.

This paper is organizing in the following structure. Section II presents the literature review that discusses related studies and applications. The definition of the problem, the proposed solution, and the project objectives are outlined in Section III. Section IV outlines the application development process used in our project. Section V discusses the limitations and future work, and Section VI concludes the paper.

II. Literature Review

We begin this section with a literature review to present previous studies that discuss topics related to the concept addressed in our project. Next, we provide a comparison of similar applications based on differing features. Finally, we present a discussion that summarizes the results and outcomes.

A. Related Studies

Teaching programming is challenging, especially when the learners are children [6], since programming concepts are difficult to understand and explain. In this literature review, we

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argue that even though programming is considered a difficult skill to learn, success in teaching children programming depends on the ways in which programming concepts are introduced.

In their 2011 study [7], Saeli et al. concluded that difficulties encountered in teaching students programming can be overcome by teaching a simple programming language such as Python or Scratch. In addition, a study conducted by Kalelioğlu and Gülbahar [6] in which the authors applied different methodologies to teach students programming found that teaching programming to fifth grade students using Scratch as a simple environment enhanced the participants' "self-confidence in their problem-solving abilities" and improved their desire to continue learning programming.

Difficulties in teaching children programming can also be overcome through the use of educational games. Singh et al. [8] found that educational games are the best method for teaching children programming because games grab their attention and provide an interesting, interactive environment. The authors provided a prototype of a simple 2D game called CQuest that aims to introduce children to basic programming concepts in a format that includes a storyline, challenges, rules, and a reward system. The game received positive feedback after being used by children and school teachers.

Another notable project is "The Game Design Studio," which aims to teach children to design games for other children [9]. This involves transforming the classroom into a game design studio for six months in order to teach students programming and help them design simple games to teach other children about fractions. Kafai argues that one effective way of teaching children to code is through letting them program their own game; she provided samples of children's work in her article.

Robots and Arduino technologies can also be used to introduce programming concepts to children in an interactive manner. Dash and dot, Bee-bot, and CodeaPillar are examples of robots designed to teach children computer science concepts [10].

It is worth mentioning that a huge global initiative called the Hour of Code aims to reach millions of students all over the world to teach them coding for free [11]. The initiative provides one-hour online coding tutorials in over 45 languages targeting different age groups, from children to the elderly. This global initiative has served over 600 million students to date.

B. Related Applications

- Kodable

This is an iOS application that is also available as a website. The application aims to provide a basic curriculum in the form of fun lessons in English to teach the basics of programming in a manner that is suitable for children aged 4–11 years [12]. This application also includes simple games that enable children to learn the basics of the JavaScript language. With a paid subscription, the application provides simplified reports that allow parents and teachers to see how their children are progressing.

- Code Karts

This is a game application available for both iOS and Android. It aims to teach children the fundamentals of coding by allowing them to acquire immediate understanding through a sequence of logical puzzles in a race game [13]. The game targets young children from age four upwards and it does not require any reading skills. Children guide race cars around a path with drag-and-drop code.

- SoloLearn

This is a programming community available on different platforms. It provides courses in various programming languages such as Java, Python, and C++ as well as tutorials and quizzes and gives learners the opportunity to challenge each other [14]. The program allows learners to discuss different issues, see each other's levels and progress, and to share code.

- Mimo

This is an educational iOS application that targets learners over 4 years old. The application teaches beginners the basics of programming through interactive tutorials and quizzes; each tutorial starts with a basic explainer and moves into an interactive question-and-answer section followed by feedback [15]. Mimo helps users learn to develop a website, build an iOS app, develop a game, and become an ethical hacker. It also teaches users to code in many programming languages.

C. Discussion

In the studies that we discussed in the literature review, researchers presented successful examples of teaching programming to children. These studies support our claim that the way programming is presented to children is highly important. We found that most researchers agreed that the best way to teach programming to children is through the use of simple programming languages and interactive environments that attract children to learn complicated concepts. Play and gaming are the most frequently used and successful methods for introducing programming to children. The aforementioned studies support the concept we employ in our project, which relies on introducing the foundations of programming to children in the form of an entertaining application using a simple programming language.

The similar applications that we outlined above helped us understand the features utilized in most successful applications and allowed us to consider the features we should employ to develop a more professional application. It also assisted us in creating an initial prototype of the structure for our application. Table I presents a comparison of the *Let's Code* application with the similar applications described above based on specific features. It is clear that none of the aforementioned applications support the Arabic language, and most of them require a paid subscription.

III. Problem Definition

Despite the importance of digital technologies and the necessity of encouraging children to learn the basics of programming for their future success, it is difficult to attract children to participate in programming education, as they tend

to perceive programming as a difficult skill [16]. Although there are several applications that aim to teach children basic programming concepts, none of them are directed toward teaching Arabic-speaking children text-based coding.

Let's code is our proposed solution. It is an interactive edutainment mobile-based application designed to teach programming to Arabic-speaking children. The application aims to teach the basics of programming in an easy, age-appropriate, and interesting way using the Python language. As Python is one of the simplest programming languages, it is a good place to start when introducing programming concepts. The application content is provided in Arabic to assist Arabic-speaking children in understanding the basics of coding. This aims to solve the problem of the language barrier that currently deters many people from learning programming. Through the development of the *Let's code* application, we are attempting to achieve the following objectives:

- Encourage children to learn programming at an early age.
- Enable Arab children to learn and understand programming concepts without requiring fluency in foreign languages.
- Integrate entertainment with education in order to motivate children to spend more time learning.
- Enhance children's problem-solving and logical thinking skills.
- Provide a creative space for children to think, analyze, and explore.
- Help parents and educational organizations support children in learning programming.
- Enrich Arabic content in the technical field.

IV. Application Development

This section describes the process through which we developed the application, starting with the information gathering techniques used in the study and proceeding to a detailed description of the system design, user interfaces, and system implementation. Finally, we present our evaluation and testing process.

A. Information Gathering

First, we conducted interviews with children aged between 8 and 12 years old on September 28, 2018. The aim was to gather information and understand children's perspectives regarding education and entertainment that utilize modern technology in general and the concept of programming in particular in order to improve the project's outcome. Fortunately, we became involved with an initiative concerned with programming that was presented by the MISK foundation, known as "Saudi Codes" [1]. The Saudi Codes initiative encourages young people to learn the basics of programming in an easy and fun environment.

Second, we conducted an online survey that received 219 responses. The target population was Arabic-speaking parents. The results of the survey indicated that 55% of Arab children spend more than two hours daily using phones, tablets, or computers. More specifically, 90% of the time children spend on those devices is on games and entertaining content while 10% is spent on educational content. We also found that most respondents think that it is important to teach children logical thinking and problem-solving skills at an early age, and about 68% of them had tried to teach their children a certain skill using technology. However, 46% of the respondents believed that foreign languages can be an obstacle to their children learning new skills. On the other hand, we found that about 41% of respondents were interested in programming, although only 8% of the respondents tried to teach programming to their children in different ways such as buying games that teach programming or joining a coding website. About 68% of those who had never tried to teach their children to program stated that they did not know how to teach, 27% stated that there is a lack of content specialized in teaching programming, and 33% of them believed that there is a lack of awareness of the significance of programming. Finally, the respondents mentioned features for educational applications that would attract their children to spend more time learning, such as attractive interfaces, usability, simplicity in explaining information, providing multiple media, and a motivating reward system. We took these responses into consideration while designing our application.

Overall, the interviews and questionnaires we conducted indicated that children spend most of the time on their devices on entertaining content; this should be taken into consideration when developing an application for children. Moreover, we found that many Arab children have difficulty understanding and interacting with English content, which encouraged us to provide the application in Arabic to help them learn programming without struggling with a foreign language. We also considered all of the respondents' suggestions in order to provide a better solution to increase the awareness and practice of programming.

TABLE. I. Comparison with Related Applications

Features\App	*Kodable*	*Code Karts*	*SoloLearn*	*Mimo*	*Let's Code*
Support for Arabic language	✗	✗	✗	✗	✓
Targets children	✓	✓	✗	✓	✓
Designed as an edutainment application	✓	✓	✗	✓	✓
Free of charge	✗	✗	✓	✗	✓
Teach Python	✗	✗	✓	✓	✓
Rewards system	✓	✓	✓	✓	✓
Allows results to be shared	✓	✗	✓	✓	✓
Text-based coding	✗	✗	✓	✓	✓

B. System Design

Let's Code is designed as an edutainment application that aims to teach Arab children to code. The application allows children to learn the basics of programming in the Python programming language using a simulated editor for Python. The target audience is users between the ages of 8 and 12 years old. We also target educational institutions that provide educational programs to children of this age. The application is designed for Arabic-speaking children, since the language used in the application is Arabic. While all explanations of programming concepts are provided in Arabic, it is helpful for users to understand the basics of English, which is used in programming syntax. The content may include simple addition and subtraction operations, so users should have a familiarity with basic mathematics. Otherwise, no special knowledge is needed.

The design of the application is important for attracting our target audience. We chose to use a "space" theme for the application and a robot character called "Labeeb" designed to guide children throughout the application. The application's storyline begins with Labeeb looking for recently discovered diamonds in the Milky Way. The child must go on an adventure with the robot, crossing multiple planets in order to find and collect these diamonds.

At the start of the game, the child moves through a series of interfaces that present audio explanations of the basic concepts of programming. Next, a home page showing a series of locked planets that the child must unlock to reach the last planet is displayed. Each planet represents a level in the application and introduces one of the programming concepts. Planets contain lessons, interactive exercises within the lessons, and end with a quiz of multiple questions that measures the child's understanding. A "Hint" option is provided with each question to assist the child if needed.

The application applies a reward strategy to motivate children. Once the child finishes a quiz, feedback is given to show which questions have been answered wrong or right and the total score represented by diamonds. If the gained score is enough, the child will be congratulated and able to move to the next planet. Otherwise, the child will be encouraged to repeat the quiz until the minimum score is achieved. The child's progress will be shown throughout the application.

The child will visit four planets providing the following programming concepts:

1) General introduction to Python and programming simple functions such as Print
2) Variables and data types
3) Boolean and logical statements
4) Loops

Finally, when the child completes all the levels successfully, Labeeb will take the child to the planet Earth to receive a certificate of completion as a prize. The certificate will contain the child's name and total score represented by the total diamonds collected throughout the trip. This certificate can be saved or shared through different social applications. Fig. 1 presents a hierarchy diagram that illustrates the screen flow and navigation through the different interfaces of the *Let's Code* application.

C. User Interfaces

This section presents a sample of screens in *Let's Code* to illustrate the user interface design (Fig. 2 to 9).

D. System Implementation

Let's Code was developed using Android Studio platform, which is the official platform for developing Android applications. We used the Java programming language as the main language to implement the application. In addition, Extensible Markup Language (XML) was used to manage the design of the application's interfaces. The application was developed incrementally; we first designed the interfaces of each level, added functions, and then tested the level to ensure that it worked properly before moving to the next level. To test the execution of the application, we used Android Virtual Device (AVD), which is the official Android emulator provided by the Android Studio platform. Additionally, we tested the application on external devices like Samsung Galaxy 9 and Huawei Mate 9 pro. *Let's Code* uses an SQLite database to save the child's information, such as their name, score, progress, and certificate. In addition, the database is used to store questions answers, keep track of the number of lessons passed, and to update the level's status (locked-unlocked). We also used the database to save videos that explain programming concepts. For the audio files, we created a folder within the application folders called raw and for pictures, we used Drawable folder, which also comes within the application files.

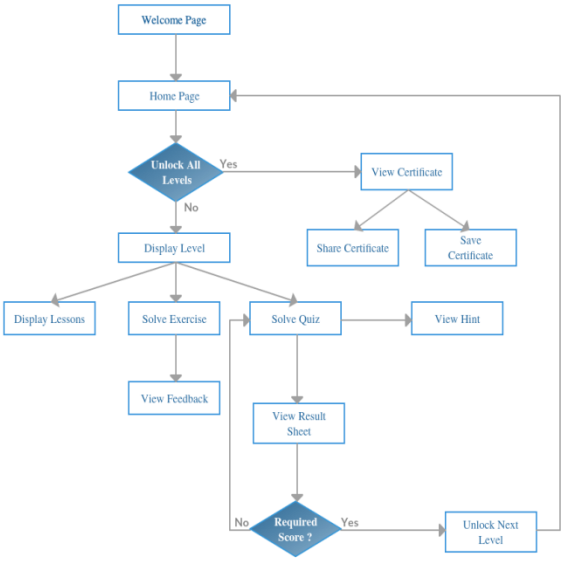

Fig. 1. Screen Flow Diagram.

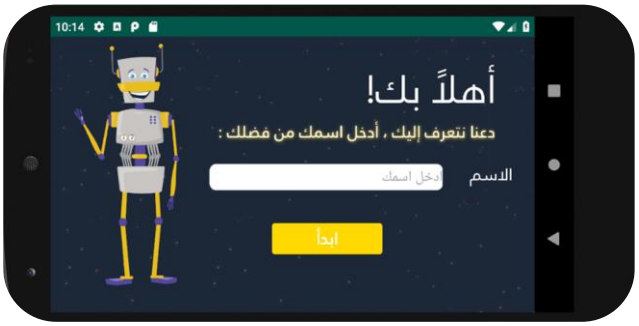

Fig. 2. Initial Screen in which the Child must Enter their Name.

Fig. 3. Welcome Screen in which the Child is Told about the Story used in the Application.

Fig. 4. Home Screen in which each Planet Represents a Level in the Application.

Fig. 5. First Lesson Screen, which Introduces Programming with Python.

E. System Evaluation and Testing

In order to detect any errors that might be made during the development phases and to ensure the effective performance of the software application, we applied several test strategies such as unit testing, integration testing, user acceptance testing, and performance testing.

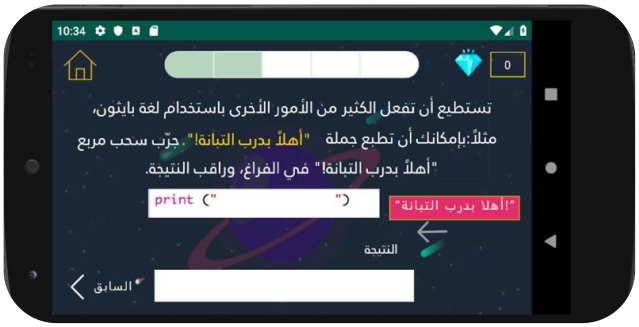

Fig. 6. First Exercise Screen in which the Child Solves the Exercise.

Fig. 7. A Question on the Quiz Screen.

Fig. 8. A Hint Screen that Helps the Child to Solve the Question.

Fig. 9. Certificate Screen that Confirms that the Child has Finished all the Levels and Quizzes Successfully.

User Acceptance Testing (UAT) is an essential step in which the system is tested by target users to ensure its acceptability and usability. UAT was conducted with six Arab children ranging in age from 8 to 12 years old. Table II displays a sample implementation of the UAT, its results, and user's feedback for *Let's Code*.

TABLE. II. USER ACCEPTANCE TESTING

User Name	**Sara AL Qahtani**			
Task	***Number of Errors***	***msec:min:sec Time Needed***	***User Feedback***	***Completion status***
Enter Name	0	01:05:48	-	Pass
View Level	0	01:17:10	"What should I do now?"	Pass
View Lessons	0	03:22:18	"Oh Allah! nice"	Pass
Solve Exercise	0	01:13:00	"I did not understand the question"	Pass
Solve Quiz	0	04:06:33	"I feel like my answer is not right"	Pass
View Hint	0	00:32:03	"Oh, now I understand"	Pass
Display Result sheet	0	00:26:23	"Oh my god! The application is nice; it is very smart"	Pass
View Certificate	0	00:11:35	"Wow! I completed it successfully!" (Clapping)	Pass
Save Certificate	0	00:23:09	-	Pass
Share Certificate	0	00:56:54	"I want to send it to my sister; I know her e-mail"	Pass

Overall, user acceptance testing showed that the application functioned as expected with no errors. It also helped us recognize enhancements that should be made for future work and highlighted contents that were strong or weak. The children were very excited to use the application, asking us "How can we download it on our devices?" It was easy for them to use and interact with the application and they were very happy and proud of the certificate they earned.

V. LIMITATIONS AND FUTURE WORK

As future work, we intend to extend the scope of our application to support a Web application platform and iOS devices. Moreover, we plan to add more levels, lessons, exercises, and quizzes that will contain new and advanced content related to Python. In addition, *Let's Code* is currently limited to Python programming language. Thus, as future work, the application may support more languages such as Java programming language.

VI. CONCLUSION

In this paper, we have provided a comprehensive description of *Let's Code*, is an educational application that enables children to learn coding. Despite the numerous applications in this field, none are directed toward teaching Arabic-speaking children to code. *Let's Code* aims to teach children the fundamentals of text-based programming in an enjoyable manner and intends to enhance children's knowledge and love of learning programming at an early age. Furthermore, it can help educational institutions and parents develop children's skills in logical and analytical thinking, and thus enable them to creatively solve problems and challenges they face. Commercially, the *Let's Code* team seeks to be supported by educational institutions to reach the largest target audience and widely achieve the objectives of the application. Finally, because technology expands and develops every day, we hope that the *Let's Code* project may provide an opportunity through which Arabic-speaking children can keep up with the development and spread of technology.

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Boosted Constrained K-Means Algorithm for Social Networks Circles Analysis

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***Abstract*—The volume of information generated by a huge number of social networks users is increasing every day. Social networks analysis has gained intensive attention in the data mining research community to identify circles of users depending on the characteristics in the individual profiles or the structure of the network. In this paper, we propose the boosting principle to find the circles of social networks. Constrained k-means clustering method is used as a weak learner with the boosting framework. This method generates a constrained clustering represented by a kernel matrix according to the priorities of the pair-wise constraints. The experimental results show that the proposed algorithm using boosting principle for social network analysis improves the performance of the clustering and outperforms the state-of-the-art.**

***Keywords*—Constrained clustering; boosting; social networks; k-means; kernel matrix**

I. Introduction

Due to the evolution in computer science and Internet, social network (virtual society) is considered a positive change in our society where a huge number of people communicate with each other, exchange information, ideas, news, etc. [1]. Social network is a social structure of individuals called "nodes" who are connected by one or many specific kinds of inter connection such as common interest, kinship, friendship, knowledge and relationships of beliefs [2]. Social network analysis has gained intensive attention in the data mining research community to identify the groups (circles) of the individuals depending on the characteristics in the individual profiles or the structure of the network (relationship between individuals). The problem of community detection in social network has been studied from three perspectives:

- Graph-based computing [3] and Graph-partitioning [4, 5, 6] which are based on the information extracted from the structure of the network.
- Machine learning principle which is based on supervised and unsupervised clustering methods that are related to the existence of labelled and unlabeled database respectively. Some clustering methods are k-mean algorithm [7], k-medoids method [8], Expectation Maximization algorithm [9] and kernel k-mean algorithm [10, 11].
- Computational Intelligence which uses bio-inspired concept in complex environments. Some algorithms based on this principle are ant colony optimization [6, 12], Genetic algorithms [13] and Iterated Greedy algorithms [14, 15].

The amount of information generated by huge number of social networks users is rapidly increasing. Consequently, this makes the analysis of social network difficult. Therefore, the researchers focused their works on Ego network. The ego network has one individual (called 'Ego') centering the network and all other individuals (called 'Alters') are connected to this Ego. Fig. 1 illustrates an example of social network that has 10 individuals, where the black node is the ego network. Social networks clustering which is named unsupervised learning, is improved by side information that are called constrained data clustering (semi-supervised clustering) that uses the pre-given knowledge (ground-truth) about the data pairs for enhancing the clustering accuracy. The two main techniques for semi-supervised clustering are the constraint-based technique [16, 17] and the distance metric learning technique [18]. The first technique supposes that data pairs of must-link constraint belong to the same cluster and data pairs of cannot-link constraint belong to the different clusters. Whereas the second technique interprets the constraint information as the distance of data pairs and computes the pair-wise similarity for data clustering to ensure a small distance for must-link constraints and a large distance for cannot-link constraints.

COP-K means method [19] is used for pair-wise constrained clustering. It is based on the k-means algorithm and it is quick and easy to implement but it generates unsteady clustering results depending on the data assignment order. The authors in [16] have modified COP K-means (MC-KM) using a mechanism that satisfies data pairs constraints in order to verb their pre-given priorities. The boosting approach is used to improve the performance of MC-KM algorithm [17]. Boosting principle is one of machine learning techniques that make a highly accurate prediction rule from relatively inaccurate rules. The boosting strategy learns many weak hypotheses by adaptive control for probability distribution of data occurrence and combines them to learn a single strong hypothesis. Adaboost algorithm [20] is the first boosting algorithm that could be used in different applications. After that, there are many boosting algorithms that have been proposed to enhance the performance of the classification methods [21, 22] and clustering methods [17, 23]. The framework of boosting for data clustering is able to enhance the performance of the clustering method using the pair-wise constraints.

MC-KM can be used as a weak learner for the boosting framework. It generates a constrained clustering represented by kernel matrix according to the priorities of the constraints that are given by the boosting approach. The elements of the kernel matrix indicate whether or not the corresponding data pair belongs to the same cluster.

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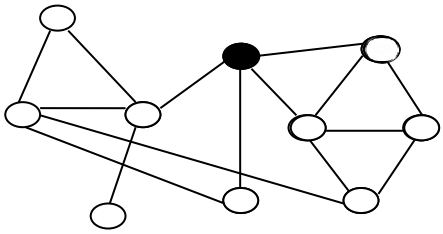


Fig. 1. An Example of Ego Network.

In this paper, we employ the boosting principle by learning constraints priorities for social networks circles discovery. The proposed method finds the communities in different social networks dataset. It uses two types of data to perform social networks clustering; profile information given by users and the topological structure of the network.

This paper is structured as follows: Section II presents the problem under consideration. Section III introduces the boosted constrained k-means method for social networks circles discovery. Section IV discusses the experimental results of the proposed method. Finally, the paper is concluded in Section V.

II. Problem Definition

The formal definition of social network circle discovery is described below. Given m group of Ego-networks $EGO = \{EGO_1, EGO_2, \dots, EGO_i, \dots, EGO_m\}$ where m is the number of Ego-network, $EGO_i = (V_i, E_i)$ is the user *i's* Ego-network i.e. the network of connections between *i's* friends, V_i is the set of users and E_i is the set of edges in EGO_i ego-network.

An edge $(u, v) \in E_i$ refers to the connection between *u* and *v* users where $(u, v) \in V_i$. The connection means that *u*, *v* users are friends, study in the same faculty, work in the same company, etc., and it depends on the nature of the social networks. Each user has feature vector via profile information or topological structure information.

The social circle discovery means to find a group of circles $C_1, C_2, \dots, C_k$ for each ego-network where C_j indicates a set of users with the same activities.

III. Boosted Constrained K-means Method for Social Networks Circles Discovery

In this section, we will employ the boosted constrained k-means algorithm to find the circles of social networks. We will use two types of the social networks information for feature vector of the users to perform the clustering; profile information given by users and the topological structure of the network.

A. Feature Definition for Social Network Circle Discovery

The circle discovery task for social network may use two types of information to carry out a comprehensive analysis on social network circles. These types are; the information extracted from the user profile and the information extracted from the topological structure of the network.

1) Features based on the user profile: Some information is encoded in the content of the user node which is called the user profile such as Facebook dataset [24]. The profile based features vector in Facebook dataset are birthday, education, first name, last name, gender, hometown, language, locale, location and work.

2) Features based on the topological structure: In common Neighbors metric, the similarity between nodes is relative to the number of their common Neighbors. Jaccard metric is one of the most common Neighbors metric that measures the network topological structure of a user as given in the following formula:

$$Jacc(i,j) = \frac{|\Gamma(i) \cap \Gamma(j)|}{|\Gamma(i) \cup \Gamma(j)|} \quad (1)$$

where $Jacc(i,j)$ is Jaccard metric between node i and node j, Γ(i) and Γ(j) are neighbours set of node i and node j respectively. The neighbours here describe the undirected edges between nodes.

B. Clustering Method based on Boosting Principle

In this paper, a constrained clustering approach based on MC-MK algorithm and the boosting principle [17] is used for community detection in social network.

BMC-KM Algorithm

Input: Data points $U = \{u_1, \dots, u_n\}$, Constraints $Con = \{(i_1, j_1, w_1), \dots, (i_{|con|}, j_{|con|}, w_{|con|})\}$ where $y \in \{1, -1\}$ and (i, j) is a pair of data index, w is the weight (priority) of constraint data pair, β, α are the parameters of loss function and k is the number of circles.

Output: The set of circles $C = \{C_1, C_2, \dots, C_k\}$

Algorithm steps:

1: Initialize the weight of each constraint

$$W_n^0 \leftarrow \frac{1}{|con|}(n = 1 \sim |con|)$$

2: For *r* = 1 to *R* do

3: Run the algorithm of MC-KM as a weak learner using Con.

4: Create a weak kernel function K_r according to clustering results as

$$K_r(u_i, u_j) = \begin{cases} 1 \text{ if } (u_i, u_j) \text{belongs to same circle} \\ -1 \text{ if } (u_i, u_j) \text{ belongs to different circles} \end{cases}$$

5: Compute the error rate ϵ_r using K_r

$$\epsilon_r = \frac{\beta}{2} \cdot \frac{\sum_{n=1}^{|con|} W_n^r (1 - y_n K_r(i_n, j_n))}{\sum_{n=1}^{|con|} W_n^r}$$

6: If $\epsilon_r = 0$ then $\delta_r = \delta^*$ and go to step 10

7: If $\epsilon_r \geq 0.5$ then $\delta_r = 0$ and go to step 10

8: Else

Calculate the value of δ_r for K_r, using ϵ_r

$$\delta_r = ln\left\{\frac{1 + \epsilon_r}{1 - \epsilon_r}\right\}$$

9: Update the weight of each constraint

$$W_n^{r+1} = W_n^r \exp\left\{\frac{-\delta_r (y_n K_r(i_n, j_n) - \alpha)}{\beta}\right\}$$

10: End for

11: Compute the final kernel matrix *K*.

$$K = \sum_{r=1}^{R} \delta_r K_r$$

12: Return the final set of circles *C* by running kernel K-means algorithm with *K*.

Boosting principle which is ensemble learning technique integrates weak hypotheses that are generated by a weak learner based on the MC-KM algorithm. MC-KM in step 3 calculates the priorities of the constraints and attempts to satisfy the constraints with higher priorities to provide different clustering results in each round. The clustering is represented by using a kernel matrix in step 4, of which each element indicates the state of data pair belongs to same circle or different circles. The weak hypothesis is used to compute the error rate in step 5 which indicates the rate of unsatisfied constraints. The value of δ_r for kernel matrix is calculated by using the value of ϵ_r. The boosting process stops according to the value of ϵ_r: when ϵ_r equal to zero($\epsilon_r = 0$). This means that all constraints are satisfied, and when $\epsilon_r \geq 0.5$ which means the weak learning condition is violated [17]. On the other hand, when $\epsilon_r < 0.5$, there is updating for the priority of each constraint using step 9. The priorities of unsatisfied constraints in step *r* of boosting process are increased but the priorities of the satisfied constraints are the same. When the boosting process is finished, the kernel matrices are integrated into a single kernel matrix *K* in step 11. The kernel k-means methods can be used for final clustering results.

The boosting process is interpreted as an optimization process to find the hypothesis that minimizes the loss function which is given as $\sum_{n=1}^{con} \exp(-y_n\, k_r(i_n, j_n))$where $K_r(i_n, j_n)$ is a function to predict where the data pair is a must-link or cannot-link and $y = \{1, -1\}$ points to the label of the data pair .The parameters *β, α* are to soften the gap in the values of the priority between the satisfied and unsatisfied constraints.

IV. Experimental Results

This section provides the experiments to evaluate the performance of the proposed method to find the circles in three datasets with ground-truth communities: Facebook, Cora and Citeseer. The proposed algorithm has been developed in Matlab 2016b and it has been tested in an Intel(R) Core(TM) i7-3630 QM (2.40GHz) and 6 GB RAM.

A. Dataset

We use two types of dataset; non-overlapping ground-truth communities; Cora and Citeseer dataset [25] and overlapping ground-truth communities Facebook dataset [24] to evaluate the proposed method. Table I gives a report about the network's statistics of the dataset where the 'Nodes' mean the users of the network, 'Edges' mean the connection between users and 'Circles' mean the communities that group users with the same activities.

The Facebook data set contains 10 Ego-networks that store and share different kinds of media information like photographs, videos and documents. This data set is considered as a real-world example with ground-truth that is correct definition for different communities of the Ego networks.

B. Evaluation Metrics

We utilize normalized mutual information (NMI) and F1-score as metrics for comparing our results with results in [15]. These metrics give a value between 0 and 1 where 1 is the optimal value. F1-score between the ground-truth circle *C** and predicted circles *C* can be calculated as:

$$F_1(C, C^*) = \frac{2 \times p(C,C^*) \times r(C,C^*)}{p(C,C^*) + r(C,C^*)} \quad (2)$$

where $p(C, C^*)$ is the precision of *C* to *C** and it is defined as:

$$p(C, C^*) = \frac{|\, C \cap C^* |}{|\, C \,|} \quad (3)$$

and $r(C, C^*)$ is the recall of *C* to *C** and it is defined as:

$$r(C, C^*) = \frac{|\, C \cap C^* |}{|\, C^* |} \quad (4)$$

NMI denotes the consistency between the ground-truth circle *C** and the predicted circles *C*. NMI can be calculated as follows.

Let *N* is the number of data points and *K* is the number of circles, *C* is the set of predicted circles and C^* is the set of ground-truth circles, then NMI can be defined as:

$$\mathrm{NMI} = \frac{\sum_{i=1}^{k} \sum_{j=1}^{k} n_{i,j}^{C,C^*} \log\left(\frac{N.N_{i,j}^{C,C^*}}{n_i^C n_j^{C^*}}\right)}{\sqrt{\left(\sum_{i=1}^{k} n_i^C \log\frac{n_i^C}{N}\right)\left(\sum_{i=1}^{k} n_i^{C^*} \log\frac{n_i^{C^*}}{N}\right)}} \quad (5)$$

Where n_i^C is the number of points in i^{th} circle in *C*, $n_j^{C^*}$ is the number of points in j^{th}circle in *C**, and $n_{i,j}^{C,C^*}$ is the number of points in both the i^{th} circle in *C* and the j^{th} circle in *C**.

TABLE. I. The Report about the Network's Statistics of the Dataset

Dataset	Nodes	Edges	Circles
Cora	2708	5278	7
Citeseer	3312	4536	6
FB ego-network0	348	2852	24
FB ego-network107	1046	27783	9
FB ego-network1684	793	14810	17
FB ego-network 1912	756	30772	46
FB ego-network 3437	548	5347	32
FB ego-network 348	228	3416	14
FB ego-network 3980	60	198	17
FB ego-network 414	160	1843	7
FB ego-network 686	171	1824	14
FB ego-network 698	67	331	13

C. Parameters Setting

The initial cluster centers are assigned using k-mean++ algorithm. The kernel k-mean algorithm with linear kernel and 1000 maximum iterations is used to get the final clustering results. The number of rounds of boosting operation is 100 rounds. The initial error rate is $\epsilon_r = 0$ and the initial $\delta_r^* = 100$. The proposed method is tested with 50% and 80% of constraints.

D. Clustering Performance

The performance of BMC-KM algorithm is evaluated against the MC-KM algorithm which is used as a weak learner. Table II. shows the results of Cora and Citseer dataset when NMI metric is used with three types of feature vector; Profile feature vector, structure network feature vector, and the fusion of the two vectors. The two algorithms are evaluated when 50% and 80% of constraints are used. The boosting principle enhances the results of MC-KM algorithm and the results with profile feature vector are the best of other two feature vectors for Cora and Citeseer dataset. This means that the profile information of users in Cora and Citeseer dataset is more discrimination then the structure of the network. When the number of constraints is increased the results of NMI are also increased. The value of NMI is 0.4243 and 0.5228 when the percentage of the constraints are 50% and 80% respectively with profile feature vector and boosted method with Cora dataset. Furthermore, NMI is 0.3308 and 0.5130 when the constraints percentage is 50% and 80% respectively with Citeseer dataset. The results of the proposed method are compared with the results in [15] as shown in Fig. 2 with Cora and Citeseer dataset. It is found that the proposed method with boosting principle gives better results than the state of the art [15]. Furthermore, the results of the proposed method for different Ego Networks that formed Facebook dataset is shown in Table III using F1-score. The performance of the Ego networks makes important variance because of the variance of the Ego network information. F1-score is increased when the percentage of the constraints that used in the algorithm is also increased. Fig. 3 shows a comparison between the proposed method and the method in [15] using F1-score. The performance of the proposed method is better than the method in [15] with Ego 0, Ego 107, Ego 1912, Ego 348, Ego 3980, Ego 414, Ego 686 and Ego 698 but it is slightly decreased with Ego 1684 and Ego 3437 due to the variance of the Ego network information. Different percentages of constraints can be used to evaluate the proposed algorithm. Once the percentages of constraints are increased, significant information is given to the algorithm and the value of evaluation metrics is increased. However, the algorithm will be slow.

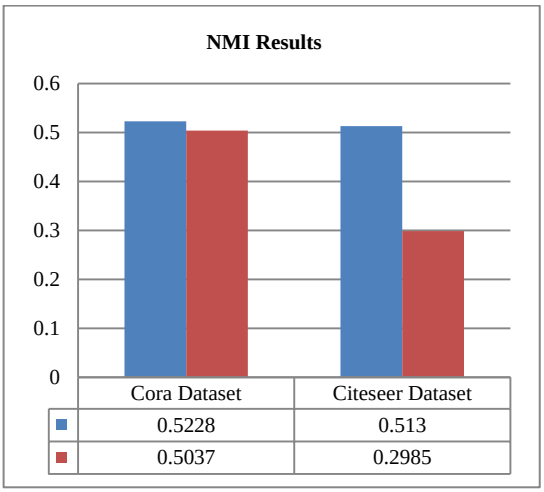


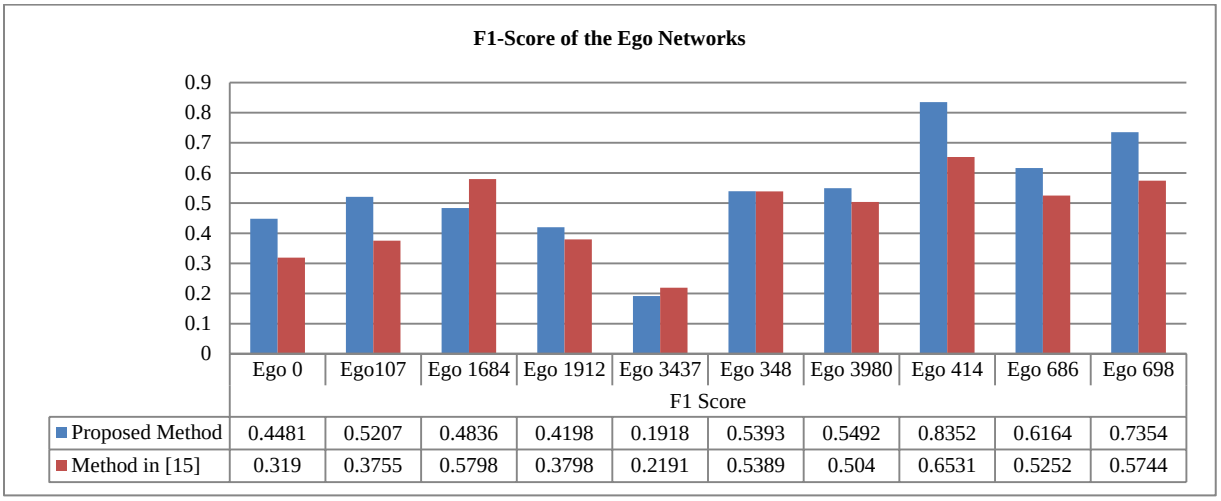
Fig. 2. The Comparison between the Proposed Boosting Method and the Method in [15].

TABLE. II. THE RESULTS OF NMI METRIC WITH THREE TYPES OF FEATURE VECTOR; PROFILE FEATURE VECTOR, STRUCTURE NETWORK FEATURE VECTOR, AND THE FUSION OF THE TWO FEATURE VECTORS WITH BMC-KM AND MC-KM FOR CORA AND CITESEER DATASET

Dataset	**Feature Vector**	**50% Constraints**			**80% Constraints**		
		Profile	***Struct***	***Fusion***	***Profile***	***Struct***	***Fusion***
Cora	BMC-KM	**0.4243**	0.0930	0.1459	**0.5228**	0.2405	0.3949
	MC-KM	0.2267	0.0930	0.0838	0.3245	0.2405	0.2553
Citeseer	BMC-KM	**0.3308**	0.2809	0.3168	**0.5130**	0.4514	**0.5130**
	MC-KM	0.2505	0.2141	0.2952	0.3079	0.2975	0.2662

TABLE. III. THE RESULTS OF F1-SCORE WITH THREE TYPES OF FEATURE VECTOR; PROFILE FEATURE VECTOR, STRUCTURE NETWORK FEATURE VECTOR, AND THE FUSION OF THE TWO FEATURE VECTORS WITH BMC-KM AND MC-KM FOR FACEBOOK EGO NETWORKS

Dataset	**50% Constraints**			**80% of Constraints**		
	Profile	***Struct***	***Fusion***	***Profile***	***Struct***	***Fusion***
Ego 0	0.2693	0.2090	0.2822	0.2926	0.3505	0.4481
Ego 107	0.3157	0.3671	0.3188	0.3555	0.5207	0.3783
Ego 1684	0.3110	0.4101	0.3847	0.4836	0.4248	0.4660
Ego 1912	0.1815	0.2407	0.2261	0.2744	0.4198	0.2549
Ego 3437	0.1139	0.1067	0.0882	0.1918	0.0845	0.1058
Ego 348	0.2738	0.4515	0.4161	0.4025	0.5393	0.4418
Ego 3980	0.2857	0.5273	0.3039	0.3454	0.4084	0.5492
Ego 414	0.4032	0.7681	0.7249	0.7317	0.8352	0.6888
Ego 686	0.3223	0.3543	0.3000	0.6146	0.6050	0.5845
Ego 698	0.3887	0.6685	0.5087	0.7014	0.6880	0.7354



	Ego 0	Ego107	Ego 1684	Ego 1912	Ego 3437	Ego 348	Ego 3980	Ego 414	Ego 686	Ego 698
	F1 Score									
Proposed Method	0.4481	0.5207	0.4836	0.4198	0.1918	0.5393	0.5492	0.8352	0.6164	0.7354
Method in [15]	0.319	0.3755	0.5798	0.3798	0.2191	0.5389	0.504	0.6531	0.5252	0.5744

Fig. 3. The Comparison between the Proposed Method and the Method in [15] using F1-score with Facebook Dataset.

V. Conclusion

This paper presented a clustering method based on boosting principle to find the circles of the social networks. The boosting framework is used with modified COP K-means method that gives priorities to the constraints. The boosting principle enhances the results of the weak learner with the three feature vectors; profile feature vector, structure feature vector and the fusion of the two vectors. The proposed method outperforms the state of the art with three datasets.

VI. Future Work

In the future, we will perform the proposed method on another dataset like Twitter and Google+ which are directed networks. Furthermore, we can use another weak learner algorithm for boosting framework to enhance the performance of social networks circles analysis.

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Collaborative Integrated Model in Agile Software Development (MDSIC/MDSIC–M)-Case Study and Practical Advice

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Abstract—The fast increase of mobile device users based on wider and easier internet access has detonated the development of mobile applications (APP) and web. Therefore, improvement and innovation have become a top priority for businesses and consumer relations. The functional quality and interface aspects in applications (software) drive companies to succeed in mobile apps market competition. This paper introduces an agile software development methodology denominated MDSIC and MDSIC-M focused on rapid application development as required by small and medium software enterprises (SMEs), and results in better quality and competitiveness. MDSIC and MDSIC - M proposes some levels with better practices that should be followed in software development projects. This article also aims to show matching indicators and results of MDSIC and MDSIC - M implementations in software projects, by assessing the needed parameters to generate quality software, and thus align technology with the goals of the organizations.

Keywords—Agile methodology; development Software (web–mobile); MDSIC / MDSIC – M; quality assurance

I. INTRODUCTION

Increasing market demand on mobile application development (APP) has detonated this industry, due to higher mobile device user adoption and wider and easier Internet access. Therefore, improvement and innovation has become a top priority in business and consumer relations. Literature does not consider full development environment to programmer demanding best practices on mobile applications development. Functional quality and interface aspects in applications to fulfill Mexican Official Norm (NOM) standards drive companies to succeed in mobile apps market competition. This paper introduces a design methodology oriented to rapid application development fulfillment required by small and medium software enterprises (SMEs), resulting in better quality and competitiveness.

Development of custom made software represents high costs for organizations and many of these projects finally do not meet its minimum requirements. Organizations with different business line want to enhance their information processes with the help of software, made by so called software factories. Those factories can help systematize and improve the processes of organizations.

According to [1] the term "software factories" conceptualizes an organization witch main objective is to produce quality software, implying a specific way of organizing work, with a considerable specialization, as well as processes formalization and standardization. For optimal software development several fundamental elements must converge to obtain a custom-made product that provides proper process functioning in organizations.

Among fundamental elements are: 1) hardware; 2) software; 3) qualified personnel (technically as well as working with processes); 4) project administration; 5) agile models for software construction. The purpose of these elements is to expedite, ease and fulfill different projects of software development towards covering organizations' objectives.

Therefore, in this paper is presented MDSIC and MDSIC-M as part of the industry. MDSIC and MDSIC-M helps to achieve a product based on norms, quality assessment based on indicators and cover needs of enterprises with line of business in software development. Web and Mobile applications (also known as APPs) have peak in development, represent a growing market and have become a priority for IT developers. Quality request of mobile applications drive companies into market competition under the standards international of quality.

Mobiles software development brings new challenges to software industry, because mobility, interconnection and simpler applications are growing in demand. In many APPs global delivery stores, tendency can be observed towards buying-selling software known as "freemium", a free license with minimum features, which can be changed by paying to access the software full features, upgrades and improvements.

Mobile applications development presents both new techniques and challenges. Recently, agile methodologies had flooded this market. Examples of these methodologies are

Extreme Programming (XP), Scrum and Agile Process Unified (AUP) [2] [3].

In this paper is presented a methodology which is based on the experience of this industry in Mexico (with survey and interviews). This experience allowed building methodological process for MDSIC and MDSIC-M development, under quality standards established by norms to be fulfilled by enterprises committed on web and mobile software development market. Also, the paper presents the results obtained from the companies that develop custom software with the use of MDSIC and MDSIC-M.

II. Literature Review

This section offers a literature review on use of different models for software development; also experiences generated using the software development model implementation (MDSIC / MDSIC - M) in Mexico. Nowadays there is a need to create software based on models that give certainty to enterprises having quality products and allowing a direct impact on their objectives. With the goal that models will aid the enterprises developing software, not otherwise, enterprises end up working for the models.

At this time software has unique challenges, such as: a) Form factors, b) User's technology, c) Usability, d) Design/user interaction, e) Programmers' choice for mobile devices implementation, f) Development processes issues, g) Programming tools, h) User interface design, i) Applications portability, j) Quality and k) Security. Additionally, look for development process time reduction.

One of the best ways to fight complexity in software development is with abstraction decomposition and problem break out. This leads to use of models that allow all the elements mentioned to interact. Business process modeling role in informatics systems (software) construction has a great importance due to these systems grow in scale and complexity, [4]. An example of business process modeling is based in theoretical concepts of the DEMO methodology, which is built upon graphical notations using Petri Networks. Both, DEMO concept and Petri Networks have been studied broadly in different research lines. DEMO methodology was developed and implemented in several real life projects [3]. Therefore, models can be found in all areas such as software engineering.

In [5], it was concluded that: "The software industry remains reliant on the craftsmanship of skilled individuals engaged in labor intensive manual tasks. However, growing pressure to reduce cost and time to market, and to improve software quality, may catalyze a transition to more automated methods". In [5], is mentioned that for the last three decades software development has been immerged in a problematic from which has been difficult to get over. The main issue on this matter is, to develop quality products that satisfy organizations' needs and objectives.

In addition, the software is not aligned with the goals and objectives of the organization. Software is built by IT experts who are dedicated to analysis, design and development, but are never accompanied by experts in the organizational processes that benefit product development in a formal way. There is a need to analyze how to improve the software industry and describe the best technologies that can be used to support this view. "Therefore, it is suggested that the current software development paradigm, based on object orientation, may have reached the point of exhaustion, and models are proposed for its successor". In the last decade, this has progressed compared to what [6], one of the creators of UML estimated in 2002.

According to [6], in that year only 5% of developers used UML in its projects and the majority used it for documentation. In several studies, [3], concluded that: "The model-driven software development (MDSD) was founded with the objective of integrating models and code as participants in software production process. The development of any system software needs to be addressed with two different perspectives: a) the perspective that addresses issues related to the application domain (the problem domain) and b) the perspective that addresses aspects of software technology used to implement the system (the solution domain). The problem domain usually has nothing to do with the software technology. For the end-user, software is a mere tool that should not cause concerns".

Author discusses in [7], the role of models as fundamental in software development to enhance elements of software reuse and facilitate the work of the different roles involved in the process. In many cases the use of models and methodologies for software development requires time, effort and investment, and if the staff is not trained delays may occur in the delivery of software projects. Here is where the models help to solve real projects and provide flexible solutions to the needs of organizations through software development.

There are different models and methodologies that function as support tools for software development. In a recent study about models and methodologies [8], conceptualize the following:

- Software development model is a simplified representation of software development process, presented from a specific perspective.
- Software development methodology: Is a structured approach for software development including system models, notations, rules, designs suggestions and process guidance.

Another way of making software is through agile methodologies, allowing carrying out a more effective and faster tracking scheme. Author in [9] says that agile methodologies follow an iterative approach to build software quickly, where the entire software development life cycle is divided into smaller iterations, which helps minimize overall risk. Agile software development approach refers to the iterative and incremental strategy involving self-organizing teams and functional teams that work together to create software. Some of the existing agile methods are: Crystal Methodologies, Dynamic Software Development Method (DSDM), Lean Software Development, Scrum and Extreme Programming (XP). Table I describes each according to their references.

TABLE. I. DESCRIPTION OF LEADING METHODS FOR AGILE DEVELOPMENT

Method agile	Description	Reference
Crystal Methodologies	A family of methods for co-located teams of different sizes and criticality: Clear, Yellow, Orange, Red, Blue. The most agile method, Crystal Clear, focuses on communication in small teams developing software that is not life-critical. Clear development has seven characteristics: frequent delivery, reflective improvement, osmotic communication, personal safety, focus, easy access to expert users, and requirements for the technical environment.	[10,11, 12, 13]
Dynamic software development method (DSDM)	Divides projects in three phases: pre-project, project life-cycle, and post project. Nine principles underlie DSDM: user involvement, empowering the project team, frequent delivery, addressing current business needs, iterative and incremental development, allow for reversing changes, high-level scope being fixed before project starts, testing throughout the lifecycle, and efficient and effective communication.	[14]
Lean software development	An adaptation of principles from lean production and, in particular, the Toyota production system to software development. Consists of seven principles: eliminate waste, amplify learning, decide as late as possible, deliver as fast as possible, empower the team, build integrity, and see the whole.	[15]
Scrum	Focuses on project management in situations where it is difficult to plan ahead, with mechanisms for ‘‘empirical process control”; where feedback loops constitute the core element. Software is developed by a self - organizing team in increments (called ‘‘sprints”), starting with planning and ending with a review. Features to be implemented in the system are registered in a backlog. Then, the product owner decides which backlog items should be developed in the following sprint. Team members coordinate their work in a daily stand-up meeting. One team member, the scrum master, is in charge of solving problems that stop the team from working effectively.	[16]
Extreme Programming (XP)	Focuses on best practice for development. Consists of twelve practices: the planning game, small releases, metaphor, simple design, testing, refactoring, pair programming, collective ownership, continuous integration, 40-h week, on-site customers, and coding standards. The revised ‘‘XP2” consists of the following ‘‘primary practices”: sit together, whole team, informative workspace, energized work, pair programming, stories, weekly cycle, quarterly cycle, slack, 10-minute build, continuous integration, test-first programming, and incremental design. There are also 11 ‘‘corollary practices”.	[17, 18]

According to [17], the XP methodology receives more bibliographical attention because it applies conceptual premises to solve a problem that is slightly different from the evolutionary development of applications. Author in [19] comments that organizations are focusing their attention to the agile methodology named Scrum. Scrum is used for managing software development, whose main objective is to maximize the return on investment for the company and generate innovation.

Author in [19], proposes that the agile development promotes stakeholder involvement in projects where those stakeholders enable monitoring of the activities, which increases productivity and profit. Agile development encourages users to participate actively in the entire product development. Author in [18] found that "Modern computer software is characterized by continuous change, very short delivery times and an intense need to satisfy customers/users. In many cases, the time-to-market is the most important management requirement. If this requirement is lost, the software project itself may lose its meaning."

In recent years the technology acceptance has been investigated by the theory of diffusion of innovations and models of social psychology [20]. The main focus of the theory of diffusion of innovations and for the adoption of an innovation is communication. Often the diffusion of innovation within a population can occur from a very small proportion, which can be modeled mathematically for selection [21, 22]. The diffusion of an innovation can be a "special kind of communication", it comes from word of mouth and the existence of adopters will depend on the influence of early users.

In [23], the author proposed in his research at the Massachusetts Institute of Technology (MIT), published in MIT Sloan Management Review (MIT SMR) and Deloitte in the spring of 2012 that "social business is an activity that uses social media, social software and social networks to enable more efficient and effective mutual connections between people, information and resources.

These connections can facilitate business decisions, actions and outcomes in different areas of the companies" [24]; report that in the coming years there will be a growing interest in building business models based on social participation, because humans have an instinctive natural desire to improve the lives of their fellowmen when possible.

A real innovative option is the collaborative integrated software development model (MDSIC / MDSIC - M); mention that "the collaborative integrated software development model (MDSIC / MDSIC - M) offers experts an easy way to interact with it through five levels that provide best practices for software development; these levels also consider the basic functions proposed by the Project Management Institute (PMI), which allows generating quality software aligned with organizational goals.

MDSIC / MDSIC - M allows evaluating software quality using a series of indicators that must be considered for optimum performance of a given software. These indicators are supported by quality standards. A key part of MDSIC / MDSIC

-M is the creation of a knowledge base that feeds through social business, which is generated using social networks (Facebook, Twitter, StumbleUpon, Pinterest, etc.), thereby producing a data bank with opinions of experts in software development; propose the use of MDSIC / MDSIC - M through a series of steps that facilitate agile project management and software development.

This model consists of five levels: 1) Level 0: Problem detection; 2) Level 1: Analysis and design; 3) Level 2: Development; 4) Level 3: Implementation; 5) Level 4: Quality indicators. MDSIC also contemplates the five basic functions covered under the Project Management Institute (PMI), which are: 1) Integration of project management; 2) Scope; 3) Time; 4) Cost; 5) Quality. Fig. 1 presents the general structure proposed by the MDSIC including its elements.

Mobile development brings new challenges to software industry, because mobility, interconnection and more simple applications are constantly growing in demand. In many APP Global-Delivery stores, this tendency can be observed, towards buying-selling software known as "freemium" (free license with minimum features that can be changed by paying to access all corners of the APP) upgrading and applications improvement, these characteristics are usually only available when a license is paid [25].

Software development for mobile platforms comes with unique characteristics used for corresponding life cycle stages. Development environment and technologies supporting mobile devices software are different compared with "traditional" development values. Another point of view is associated to restrictions of mobile applications, which is described in [26]. The author mentions two types of those restrictions: 1) constant and inherent evolution and 2) evolution restrictions such as: bandwidth, coverage and security.

On the other hand, inherent limitations, such as limited screen display, limited text capturing capacity (limited keyboard, for instance), memory capacity, processing power, slow startup and execution, are permanent, at least when compared to desktop environments. Programmers have attacked these limitations with agile development approach. Using agile methods for software development has a lot of approval but in some cases it also has opposition.

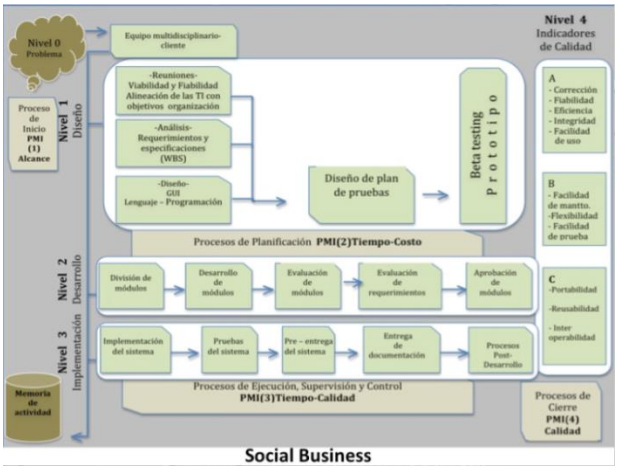

Fig. 1. Collaborative Integrated Software Development Model (MDSIC).

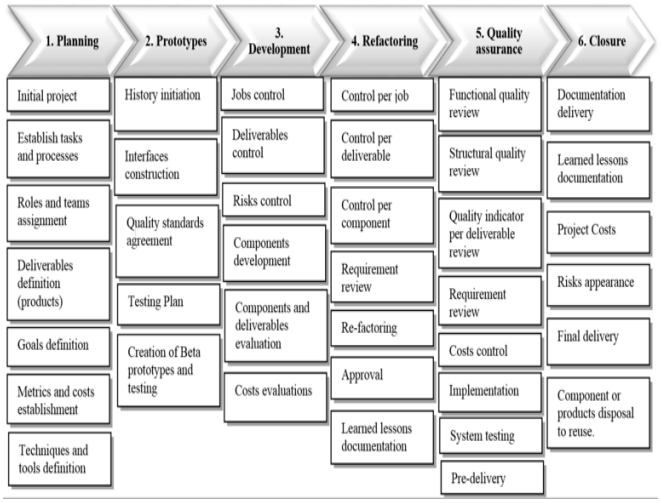

Fig. 2. Stages and Processes in MDSIC-Mobile Methodology with Reuse, Best Practices Approach.

The methodology proposed considers all of the four levels explained in MDSIC (stages 1, 2, 3 and 4) and adds control using scheduler and QA in development teams (stages 2 and 5); who can use a methodology of extreme programming, by pairs, or other method. In Fig. 2 stages to assure a quality mobile development are shown.

There is also uncertainty when distinguishing ad-hoc programming agile methods and development needs. However, as shown in [27], agile methods provide an organized development approach. In [28], a researchers group analyzed publications and agile development advances in the past 10 years, standing out XP methodologies, Scrum, Lean, Crystal, among others.

III. Methodology

The methodology of this research was to implement MDSIC and MDSIC - M in different projects and use its indicators to measure the quality of the software produced. Having identified the problem, the research objectives were established and the nature of the investigation, which defines procedures to obtain the information needed to solve the problem is described.

A fundamental part of this project is to evaluate and measure indicators in SMEs developing mobile applications. In order to do it, a transversal study was performed, and the investigation landscape included: quantitative, field research in software development, quasi-experimental studies and explanative [29]. A synthesis analysis of different models and methodologies found in the literature was driven, from this analysis were gathered variables needed to measure and propose a methodology ad hoc [5] [30]. In Fig. 3, it is shown the methodological process.

Utilizing the main models and methodologies characteristics analyzed, questions were obtained to determine the importance of a mobile application development, using planning edges, costs, risks, quality programming [31] and metrics [32]. To establish the number of probable enterprises, several databases were reviewed, and census population was obtained. The databases inspected were AMITI [33], Yellow

Section (YP) [34], infoisinfo (IiI) [35] and finally it was an investigation of Mexican Enterprise Information System (SIEM) of Economic Development Bureau (SEDECO) [36], giving the next table results, you can find in Table II.

According to previous data, the survey for populations was calculated based on a confidence interval of 95% and 97% [38], Table III shows the results.

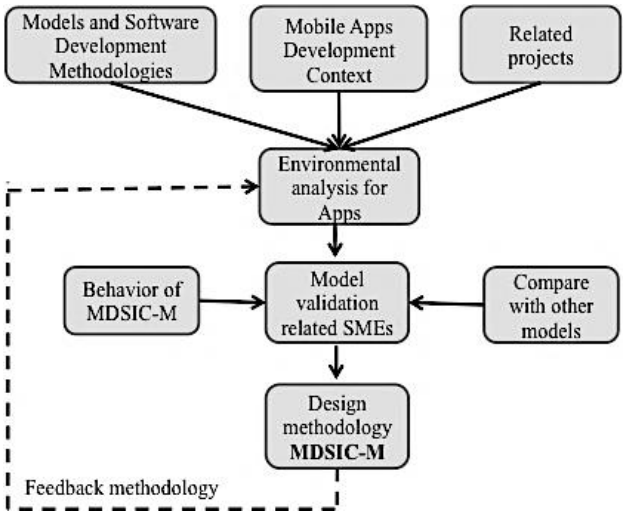

Fig. 3. Methodological Process for MDSIC-M.

TABLE. II. POPULATION ANALYSIS FOR THE APPLICATION OF SURVEYS BASED ON SEARCH TAGS

States	Active population*	YP	IiI	SIEM	Population %
Ags	510,541	18	23	5	6 %
Col	342,702	17	14	12	4 %
Gto	2,412,886	38	32	15	27 %
Jal	3,369,238	75	14	59	37 %
Mic	1,896,174	20	6	24	21 %
Nay	529,436	3	4	5	6 %
Total	9,060,977	171	93	120	

* INEGI [37]. Economically-active population.

TABLE. III. POPULATION CALCULATION WITH A STANDARD ERROR OF 5%

Population Calculation				
Confidence interval	**YP** (171)	**IiI** (93)	**SIEM** (120)	Average
97%	126	78	96	100
95%	119	75	92	95

Surveys were carried out with support of social networks in order to reach enterprises; 70 companies answered, only 38 of those develop mobile applications (54%). In Fig. 4, 5, 6, 7, 8 and 9, the survey's results are shown (including open questions).

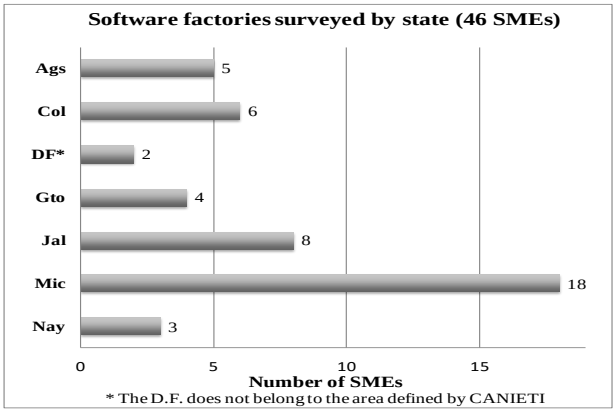

Fig. 4. SMEs Pooled by State on the Region (66% Answered, 46/70).

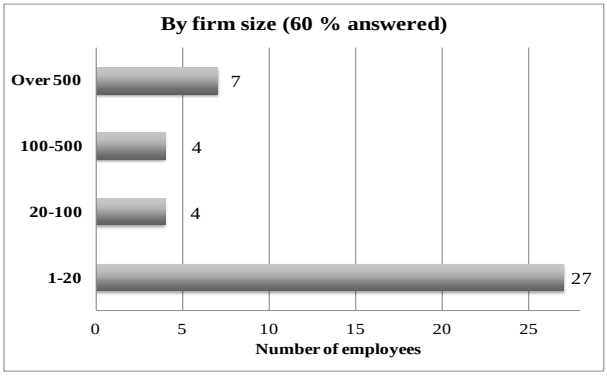

Fig. 5. Enterprise Size, based on Answers (42/70).

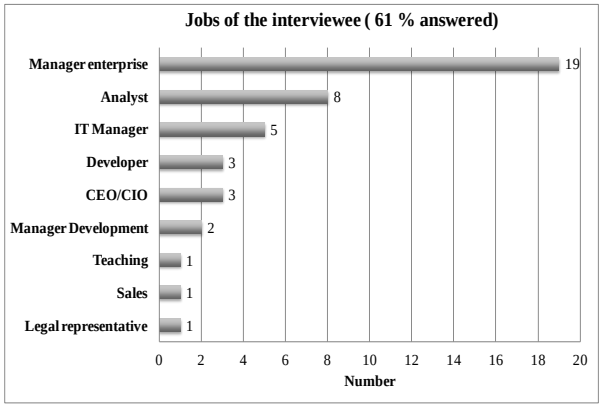

Fig. 6. Current Position on the Ones Pooled (43/70).

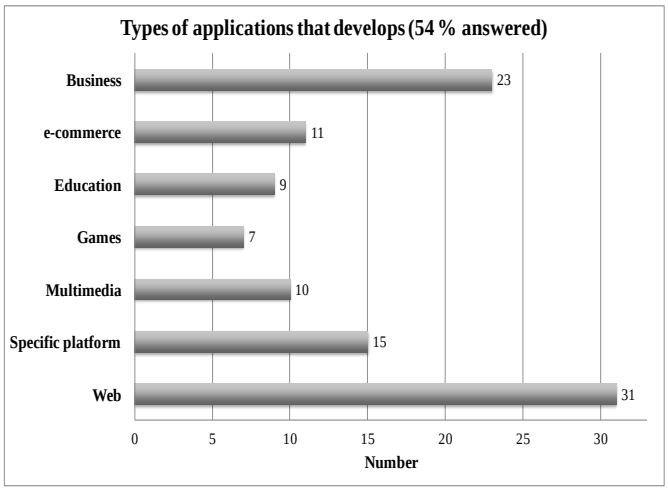

Fig. 7. APP Type Developing (38 SMEs Answered).

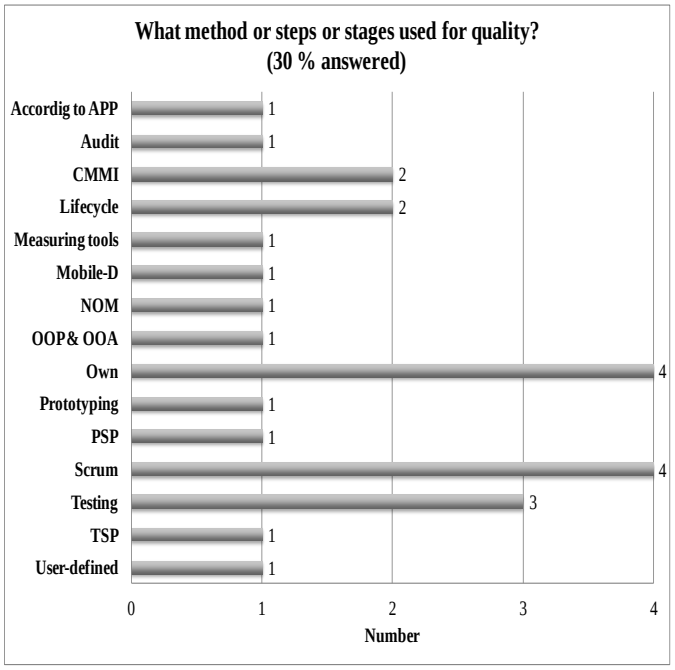

Fig. 8. Quality Analysis Methodology (21/70).

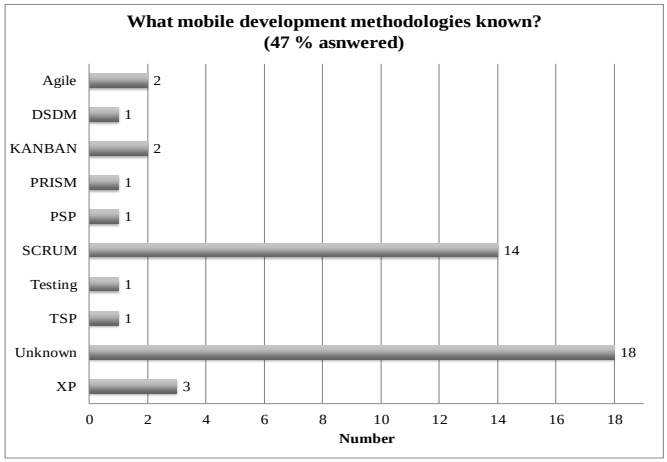

Fig. 9. Mobile Development Methodology Known by SMEs (33/70).

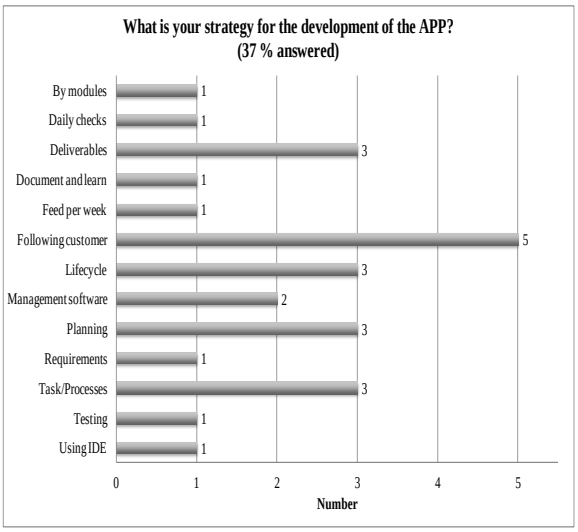

Fig. 10. Strategy to Develop an APP and be Competitive (26/70).

Finally, companies were asked about their strategy to develop an APP and be competitive, in Fig. 10 the result is displayed.

IV. Results

A methodological framework was generated that was used to propose and validate the methodology shown in Fig. 10 in which the elements considered, into account for software development are described. The existing methodologies, the context of mobile development and related projects are the source of this analysis. A model was created and their behavior was observed in SMEs, which helped to provide feedback methodology in order to obtain the best proposal [39].

To guarantee quality in development, the methodology was based on the following components that should be oriented to collaboration and project's plan maintenance: 1) requirements definition (Tasks and deliverables), 2) initial plan (WBS), 3) establishment of WBS and deliverables, 4) construction of a job control planner, 5) deliverables control, 6) risks control, 7) costs and metrics control (establishment), 8) Quality assurance (KPIs and project scope), 9) Collaborative tool usage based on Scheduler, 10) Testing plan and delivers (deliverables) and 10) document learn lections (project information database).

The scheduler is the methodology core; sustains the follow up to the proposed activities in WBS, and in best practices proposed in PMI agile and Lean [40]. MDSIC-M contemplates the next elements, Fig. 11.

An essential part of MDSIC and MDSIC – M is the "activity report", which has a presence through a system that is implemented based on a technology known as "responsive web", which is a way of programming that allows the system to adapt to the size and shape of any device that connects to it. The software accompanying MDSIC/MDSIC M aims to capture and store the information generated from software projects. In addition to creating a knowledge base enhanced by expert developers looking to propose improvements in the processes of software development. This allows collaborative work from its multiuser nature as shown in Fig. 12 and 13.

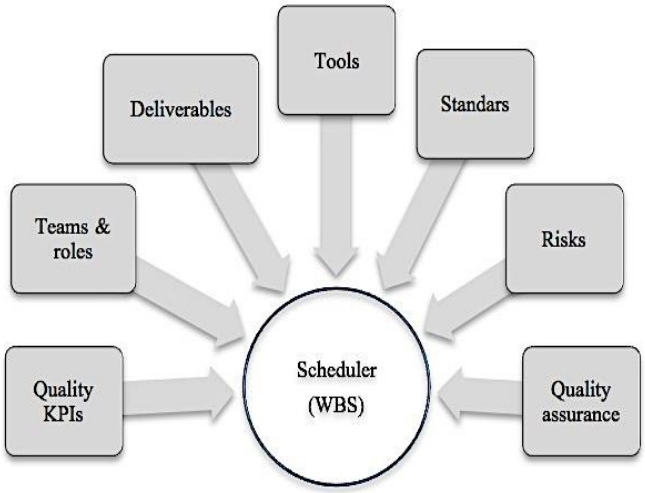

Fig. 11. MDSIC-M Elements to Assure Quality in APP Development.

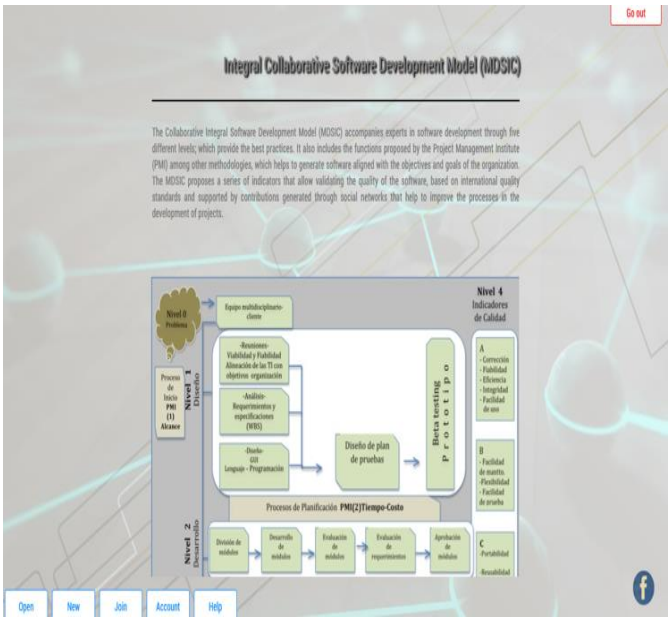

Fig. 12. Welcome Interface in MDSIC v1.0.

The projects developed through MDSIC v1.0 and v2.0 has the facility to measure the progress of these projects through the quality module, which allows measuring the progress of each of the levels. Thus the project manager, quality assurance (QA) and the collaborative team can measure the progress of each project graphically according to plan.

This type of projects seeks to be delivered quickly and having beta prototypes allows an organized development, contemplating quality standards by having processes and quality evaluations [40]. "Global delivery" is left out of this methodology; however, it can be an opportunity to upgrade in the future in order to fulfill the mobile development process. Experimental tests with regional enterprises have been carried out to observe the utility of this methodology and to gather information whether or not is a good alternative for software factories in Mexico, see results in Fig. 14 and 15.

It has been observed that there is a rising demand for Web applications. The proposed methodology can be applied for this type of development and gain a competitive advantage; a future project is to prove this Web development approach and document its behavior.

You can see in Fig. 16 the comparison between different methodologies that use quality indicators.

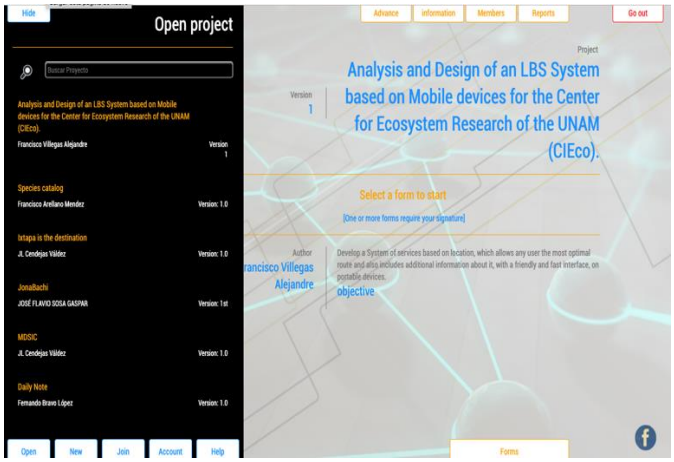

Fig. 13. Project Selection Interface in MDSIC v1.0.

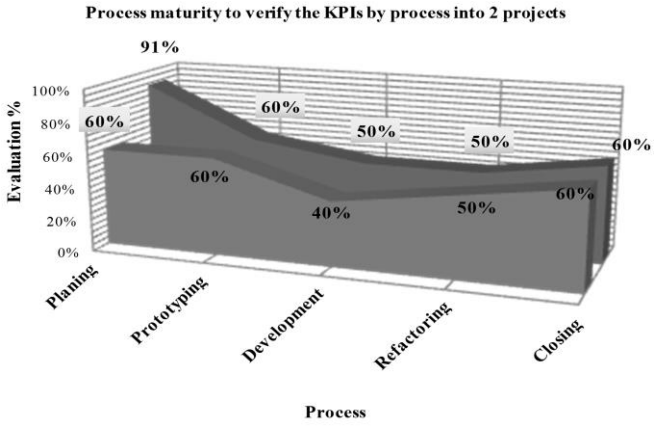

Fig. 14. Verify KPIs in MDSIC-M.

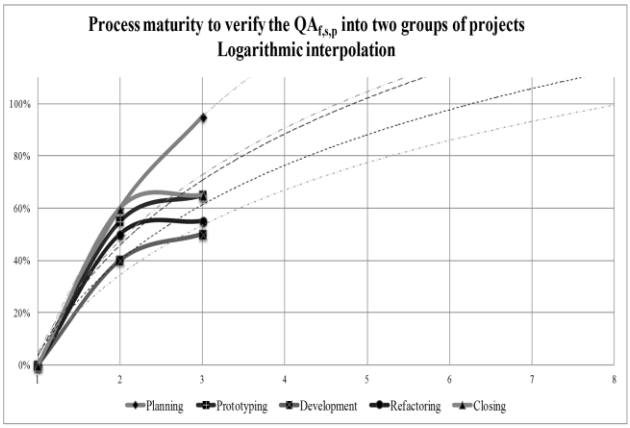

Fig. 15. QA Process Maturity.

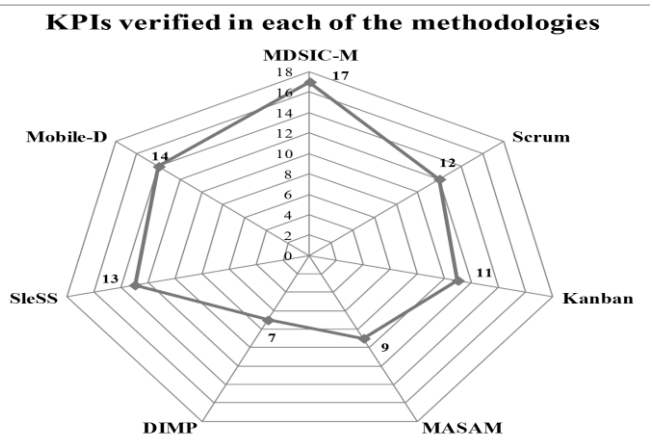

Fig. 16. KPI used in different Methodologies [31].

V. Conclusion

The problems identified in the field of software development in the last three decades is mainly due to not having well defined methods for building software; this can be offset by using the model MDSIC; it has proven to be a tool that helps software development companies to develop projects that line up with the goals and objectives of organizations, thus contributing to their productivity. MDSIC aims to integrate all involved by forming teams of collaborative work that allow significant progress in building the software.

The need for documenting software projects is very important and MDSIC, with its system MDSIC v1.0, enables to register and document all the processes of software development. This application has multi-user features and was designed to function as a responsive technology; MDSIC v1.0 automatically adjusts to any device. This work contributes with relevant information to research focused on software engineering and process modeling, in addition to professionals in the use of agile methodologies, allowing the identification and best practices to achieve success in agile software development. In the area of statistics, this study confirms that research in software engineering can be certified and validated by the multivariate analysis. Furthermore, the work contributes a quantitative research that encourages organizations to use agile principles in software development.

CMMI and MOPROSOFT propose stages or maturity levels on software factory creation. The evaluated KPIs in MDSIC-M will be a significant aid to achieve the objective in accordance with a standard or quality norm. The generation of documentation and reports provided by MDSIC 2.0 offers an easy way to reach this goal. Finally, as an advantage the methodology proposes to store project histories, documenting size, time, costs and risks that took place during the project, allowing the Company to consult this database and not repeating the mistakes, improving its development process. Reused components are the best alternative to be competitive in mobile development market.

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Low Power and High Reliable Triple Modular Redundancy Latch for Single and Multi-node Upset Mitigation

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***Abstract*—CMOS based circuits are more susceptible to the radiation environment as the critical charge (Q_{crit}) decreases with technology scaling. A single ionizing radiation particle is more likely to upset the sensitive nodes of the circuit and causes Single Event Upset (SEU). Subsequently, hardening latches to transient faults at control inputs due to either single or multi-nodes is progressively important. This paper proposes a Fully Robust Triple Modular Redundancy (FRTMR) latch. In FRTMR latch, a novel majority voter circuit is proposed with a minimum number of sensitive nodes. It is highly immune to single and multi-node upsets. The proposed latch is implemented using CMOS 45 nm process and is simulated in cadence spectre environment. Results demonstrate that the proposed latch achieves 17.83 % low power and 13.88 % low area compared to existing Triple Modular Redundant (TMR) latch. The current induced due to transient fault occurrence at various sensitive nodes are exhibited with a double exponential current source for circuit simulation with a minimum threshold current value of 40 µA.**

Keywords*—Multiple Event Transient (MET); Single Event Upset (SEU); Single Event Transient (SET); Radiation hardening; Reliability; Transient fault; Triple Modular Redundancy (TMR)

I. INTRODUCTION

The reliability issues are a major concern in semiconductor ICs designed for medical, space and defense applications that operate in a high radiation environment. As the CMOS technology scaling down, the supply voltage and node capacitance scales down as well. When high energy neutron or alpha particles passes through the MOS device, it causes an additional charge (excess electron-hole pair) induced in the substrate [1]. In specific, the sensitive node is the drain terminal of the OFF transistor. The induced additional charge collects by the drain terminal and turns on the device, causing in a voltage transient (or glitch) at the output. These glitches are called transient faults and are temporary in nature. Modelling the effect of transient fault on both NMOS and PMOS is shown in Fig. 1. To model the impact on NMOS transistor the double exponential current source is connected between the drain and source terminals of NMOS transistor as shown in Fig. 1(a). If the transient fault occurs on the drain terminal of NMOS transistor, a negative current spike is generated [22]. If the input gate voltage, $V_G = 0$ at that moment, V_{GD} becomes greater than the threshold voltage (V_{TN}), i.e. $V_{GD} > V_{TN}$ which runs the transistor in triode region. The output node then pulls down to logic 0.

To model the impact on PMOS transistor, the double exponential current source is connected as shown in Fig. 1(b). If the transient fault occurs on the drain terminal of PMOS transistor, positive current spike is generated. As a result the output node pulls up to logic 1. The output node recovers by removal of the current source [2]–[4]. If this transient pulse is propagated through memory element then, the Single Event Upset (SEU) occurs.

To evade these radiation effects, many hardened by design techniques have been proposed to deal with Single Event Transients (SETs), SEUs and Multiple Event Transients (METs) [5]–[21]. The advantages of these methods are that they are highly resistant to SETs and SEUs. The cost in terms of power dissipation, delay and area consumption for protecting memory elements from an SEU is substantial. SETs and SEUs are more general observed errors whereas, METs may occur due to packing density or single event triggering multiple transients.

This paper suggests a low power, less area and fully robust triple modular redundancy latch design (named as FRTMR) latch. The suggested latch is less sensitive to SEU and Multiple Event Upsets (MEU). The FRTMR latch comprises of three identical latch structures and a novel majority voter circuit. The three identical latch structures consist of six feedback loops (three of them will be active when the output of inverters INV1, INV2 and INV3 are 0 and the other three will be active when the output is 1). This saves power dissipation. The majority voter circuit designed with less number of transistors and less sensitive nodes compared to the existing classical TMR latch used in [12]. With less number of sensitive nodes, the probability of affecting the circuit due to transient faults is also less. FRTMR consumes considerably low power and less area than the existing classical TMR latch because of the less number of transistors used in majority voter circuit. Detailed analysis of FRTMR latch is presented in Section III.

The remaining sections of the paper are organized as follows: Section II discussed about some existing hardened latches. Section III describes the implementation, detailed analysis of proposed FRTMR latch with and without transient faults. Performance comparisons with existing latch are reported in Section IV. Section V concludes the paper.

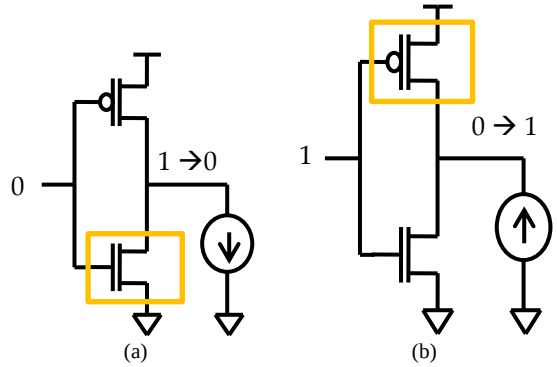

Fig. 1. Transient Fault Current Model on: (a) NMOS; (b) PMOS.

II. Related Work

Fig. 2 shows the conventional D-latch. This latch cannot function properly in highly radiated environments. During the latch mode, if a high energy particle strikes on the intermediates nodes n1 or n2. It may disrupt the state of the latch. This results in a wrong value at the output. To overcome this problem, many radiation-hardening latches have been proposed in the literatures.

Fig. 3 presents the circuit of the LCHR latch in [7]. The latch includes three redundant information retention feedback loops, which allows SEU to be tolerated in hold mode. The latch is capable of filtering single event transients arrived at input due to hysteresis property of Schmitt trigger (ST) inverter. Nevertheless, this circuit has following disadvantages: 1) in hold mode, there is a possible current competition, because the result is driven by a feedback loop and a C-element. This leads to more power dissipation. 2) Not economical because of area overhead and power dissipation. 3) Not completely self-recoverable from SEUs like DICE latch.

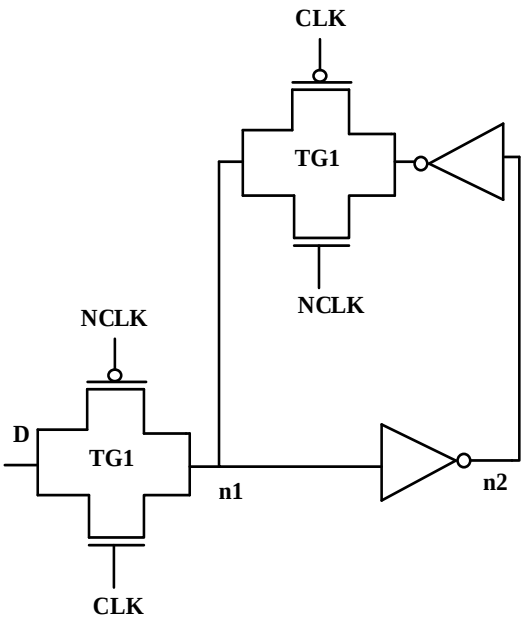

Fig. 2. Conventional Latch Structure.

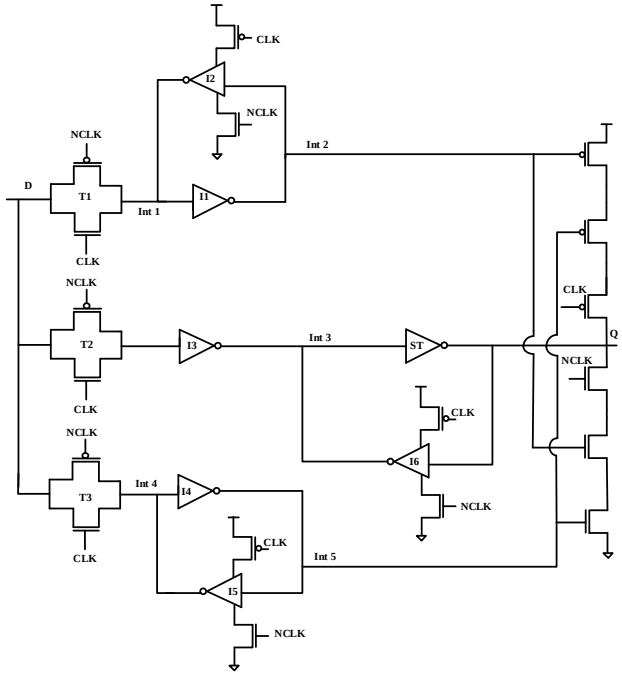

Fig. 3. LCHR Latch in [7].

The SEU resilient and SET filterable latch (RFEL) in [8] is presented in Fig. 4. This latch also includes three redundant information retention feedback loops in order to handle single node upsets due to particle strikes. The circuit uses a ST inverter in order to filter SETs in transparent mode of operation. But, the ST inverters cannot tolerate high energy particle strikes.

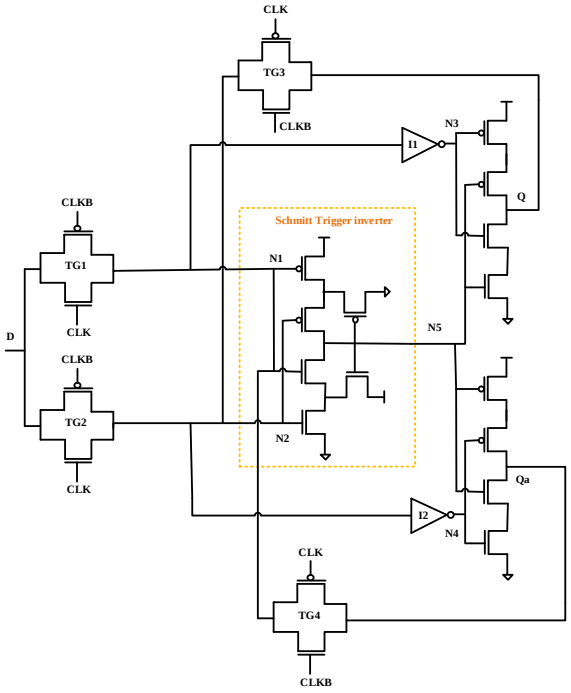

Fig. 4. RFEL Latch in [8].

Fig. 5 illustrates the latch circuit in [9]. The latch comprises of two interconnected structures. These cross-coupled structures form a negative feedback path. Feedback path for the latch are cut-off in transparent mode to improve the performance in terms of speed. In the latch mode, feedback structure enables to restore temporary failures because of SEUs. However, it cannot tolerate high energy particle strikes, and also consumes large silicon area.

The latch design in [10] is shown in Fig. 6. It comprises of a static D-latch and an error detection circuit. Error detection circuit plays a major role in mitigating soft errors. However, if the transient fault occurs on error detection circuit, it produces an erroneous value. Also, it has an extensive area overhead and power dissipation.

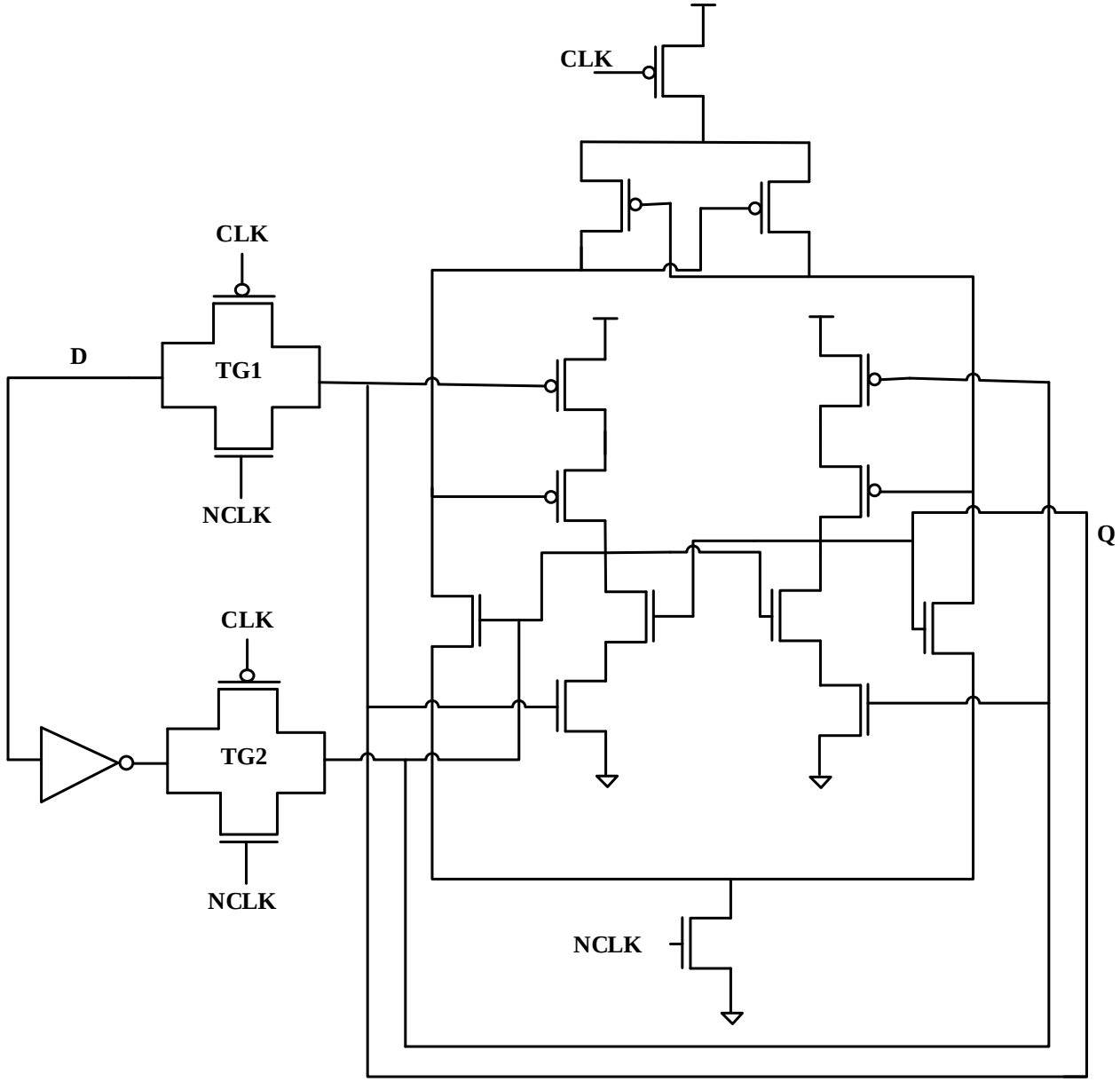

Fig. 5. Latch in [9].

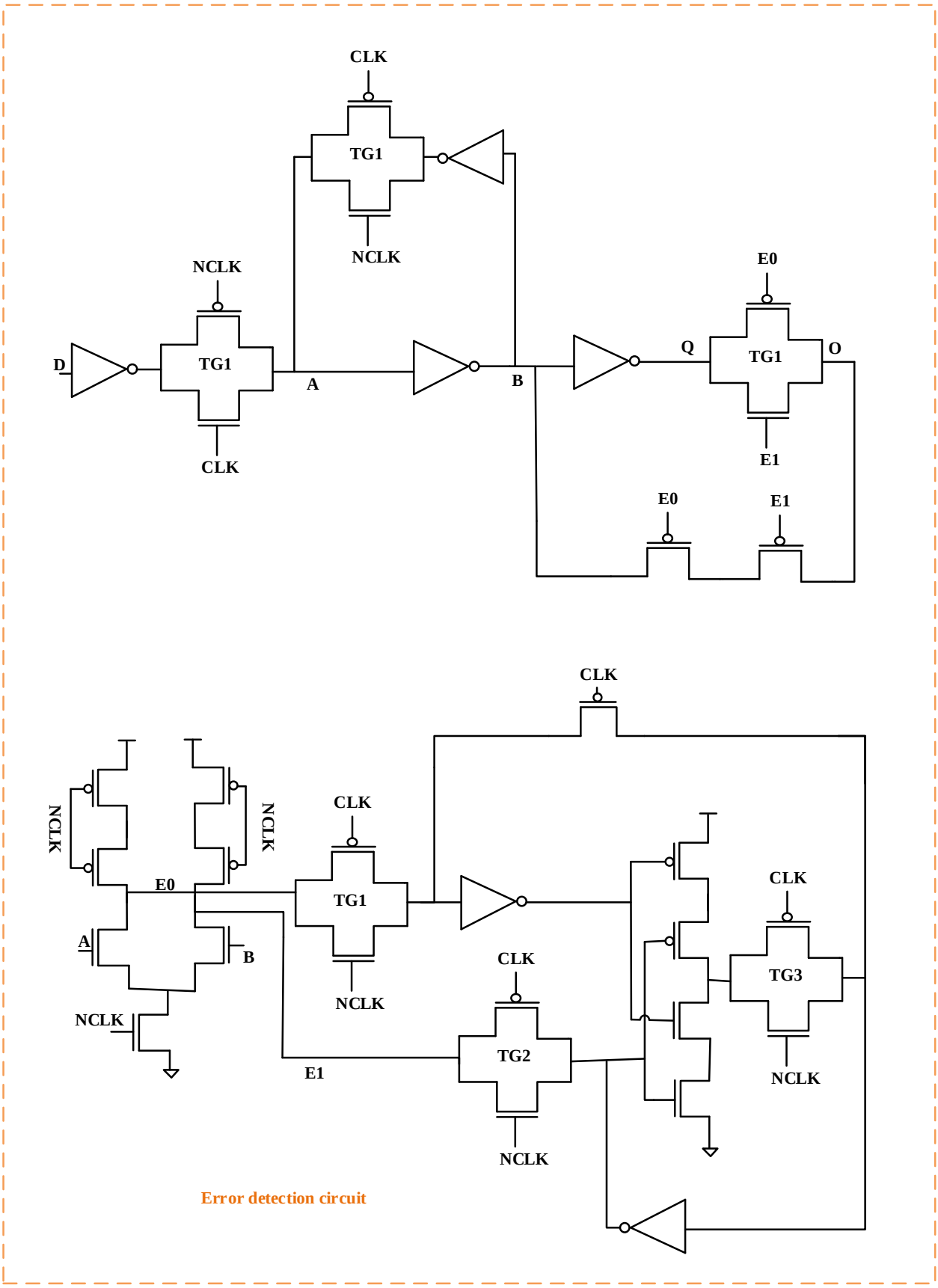

Fig. 6. Latch in [10].

The latch designed in [11] is shown in Fig. 7. It consists of three transmission gates, a memory element and a clocked Muller C-element to save power dissipation. Nonetheless, it cannot tolerate multi-node upsets and also if the transient fault occurs on intermediate nodes of C-element it produces a glitch at the output. SEU tolerant latches to mitigate the single event upsets also include DICE, Quatro [20] and TMR latch used in [12, 13]. All the above discussed latches are not multi-node upset tolerant.

The classical TMR latch is presented in Fig. 8. It consists of three identical latch circuits which individually perform the same operation and these results are processed by a majority voter circuit to produce a solitary output. It can tolerate SEU occurring on any one of the three identical latches, as long as the other two inputs continue to be stable, and provide 100% SEU immunity on the internal nodes N1 (or A), N2 (or B) and N3 (or C). In this paper these nodes are signified as "self-recoverable" (SR) nodes as the output can be self-recovered from any type of single node upsets. Nevertheless, an SET on the internal nodes (n1 – n5) of a voter circuit can cause a voltage transient at the output. These nodes are named as "critical nodes" (CN) as the output can't be recovered themselves until and unless the transient pulse is removed from the critical nodes.

Though, TMR latch is most prevalent hardened technique used in aerospace applications for its high reliability, many researchers tend to develop radiation hardened latch designs using the following techniques: 1) ST inverter. 2) Muller C-element. 3) DICE principle. 4) Error correction mechanism. The primary reason is that it incurs huge area and power dissipation. Also, the number of critical nodes is more. In addition to this, the existing TMR latch is not suitable for multi- node upsets. Our proposed FRTMR latch in section III resolves these issues properly.

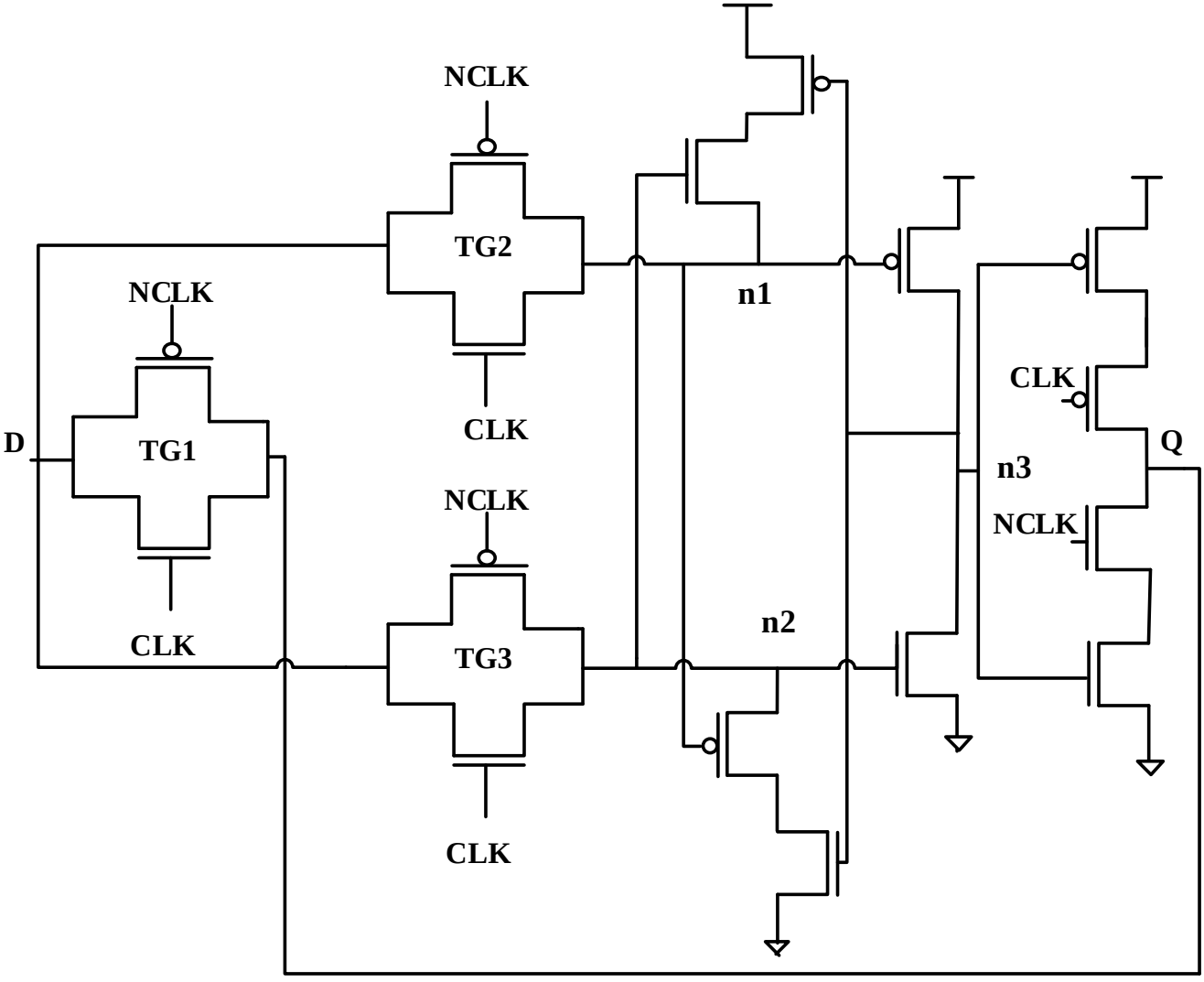

Fig. 7. Latch in [11].

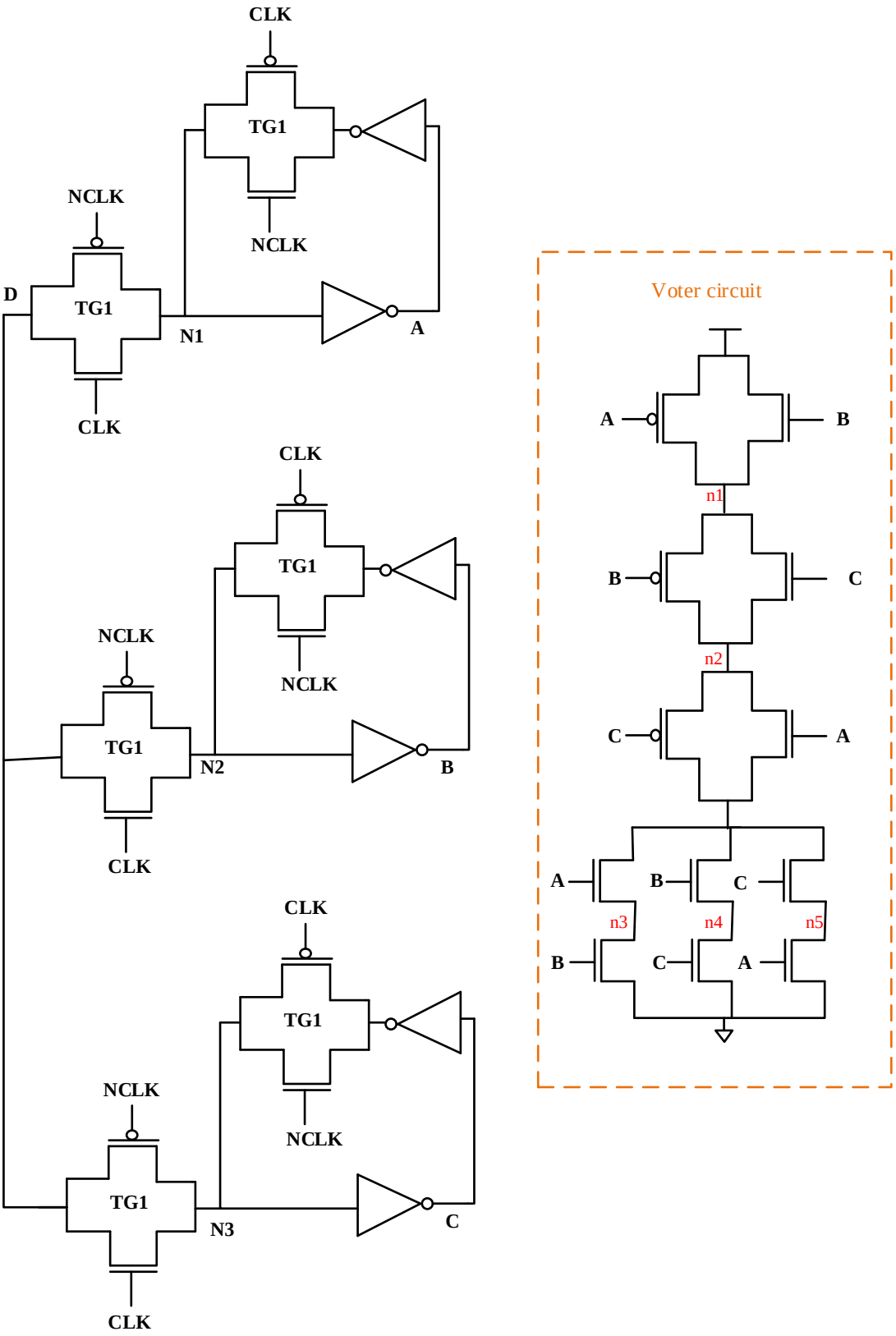

Fig. 8. Classical TMR Latch.

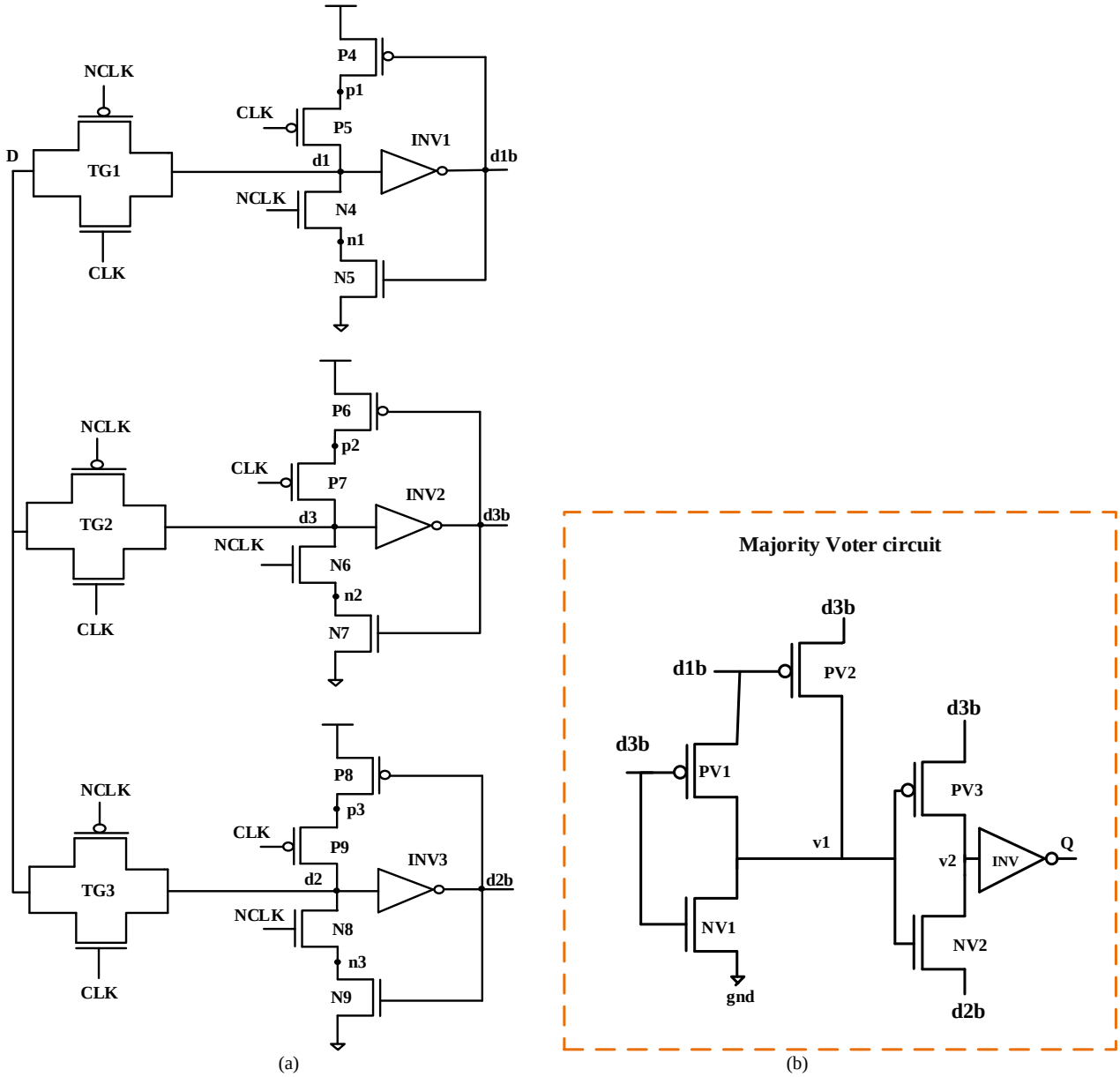

Fig. 9. Proposed FRTMR Latch: (a) Three Identical Latch Configurations; (b) Majority Voter Circuit.

III. Proposed FRTMR Hardened Latch

The proposed FRTMR latch is shown in Fig. 9. From Fig. 9, it can be observed that the three identical latch circuits shown in Fig. 9(a) perform the operation and the results are processed by a majority voter circuit shown in Fig. 9(b) to produce a solitary output. According to Fig. 9, D, Q, CLK and NCLK are input, output, system clock and system negative clock respectively.

During transparent mode (when CLK = 1 & NCLK = 0) the transmission gates (TG1 – TG3) are ON. For D = 0, (i.e., d1 = d3 = d2 = 0) the PMOS transistors of INV1 – INV3 are ON which results in d1b = d3b = b2b = 1 and subsequently, these values are fed to majority voter circuit. In the majority voter circuit for d1b = d3b = d2b = 1, transistors PV1 and PV2 are OFF, NV1 is ON and hence, V1 = 0. Consequently, node v2 = 1 through PV3 transistor. This v2 node voltage propagates through inverter (INV) and produces the output Q = 0.

For D = 1, (i.e., d1 = d3 = d2 = 1) the NMOS transistors of INV1 – INV3 are ON which results in d1b = d3b = d2b = 0 and subsequently, these values are fed to majority voter circuit and makes v1= 0. As a result, node v2 = 0 and hence, output Q = 1.

During latch mode (when CLK = 0 & NCLK =1) the transmission gates (TG1 – TG3) are OFF, and hence, the internal nodes retain their current values through the NMOS transistors of feedback loops for D = 0 and PMOS transistors of feedback loops for D = 1. As a result, the latch outputs the correct value in the latch mode.

Now, the detailed working of FRTMR latch in the presence of transient fault at various internal nodes (d1, d3, d2, d1b, d3b, d2b, v1 and v2) is explained in this section. Note that, the

storage of 0 of the latch is considered for all fault-tolerance discussions throughout the paper. In normal operation (without transient fault) for data input D = 0 case, d1 = d3 = d2 = v1 = Q = 0 and d1b = d3b = d2b = v2 = 1. In general, SET is analyzed only in latch mode.

SET on node d1: In this case, d1 flips its state from 0 → 1, and the corresponding node d1b changes its state from 1 → 0. Therefore, the node voltages at d1b, d3b and d2b are 0, 1 and 1 respectively. These values are fed to majority voter circuit. In the majority voter circuit for d1b = 0 and d3b = d2b =1, transistor PV1 is OFF, PV2 and NV1 are ON simultaneously. In order to perform the latch operation correctly, PV2 transistor in the majority voter circuit shown in Fig. 9(b) is sized 10 times (i.e., W/L = 1500 nm/45 nm) faster than NV1 (i.e., W/L = 150 nm/45 nm). The sizing of these transistors helps in maintaining the value of v1 at logic 1. As a result, the node v2 becomes 1. This v2 node voltage drives the inverter (INV) and produces the correct output. The voltage levels at node v1 for various W/L ratios of PV2 and NV1 for different combinations of d1b, d3b and d2b are shown in Fig. 10.

SET on node d3: In this case, d3 flips its state from 0 → 1, and the corresponding node d3b changes its state from 1 → 0. Therefore, the node voltages at d1b, d3b and d2b are 1, 0 and 1 respectively. These values are fed to majority voter circuit. In the majority voter circuit for d3b = 0 and d1b = d2b =1, transistors NV1 and PV2 are OFF, PV1 is ON and hence, v1= 1 and successively, v2 = 1. This v2 node voltage is propagated through inverter (INV) to produce the correct output.

SET on node d2: In this case, d2 flips its state from 0 → 1, and the corresponding node d2b changes its state from 1 → 0. Therefore, the node voltages at d1b, d3b and d2b are 1, 1 and 0 respectively. These values are fed to majority voter circuit. In the majority voter circuit for d2b = 0 and d1b = d3b =1, transistors PV1 and PV2 are OFF, NV1 is ON and hence v1 = 0 and successively, v2 = 1 through PV3 transistor. This v2 node voltage is propagated through inverter (INV) to produce the correct output. The analysis is same for d1b, d3b and d2b.

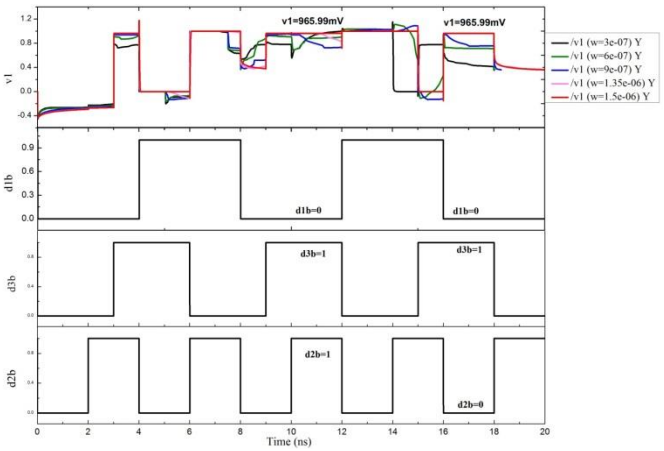

Fig. 10. Parametric Analysis to Determine the width of the Transistors W_{PV2} /W_{NV1}..

SET on node v1: Without transient fault for D = 0, d1 = d3 = d2 = 0, d1b = d3b = d2b =1, and the internal node v1 and v2 are 0 and 1 respectively. Now, If transient fault occurs on node v1, it flips its state from 0 → 1. Subsequently, node v2 becomes 1. This v2 node voltage drives the inverter (INV) and produces the correct output.

SET on node v2: If the transient fault occurs at node v2, it produces glitch at the output immediately and remains until the transient fault effect presents at the node. The output will be recovered after the transient fault dies down. In the proposed latch, internal nodes d1, d3, d2, d1b, d3b, d2b and v1 are termed as "self-recoverable" nodes and v2 as "critical node".

Fig. 11 shows the simulation results of FRTMR latch for without and with transient fault injections (highlighted in the Fig. 11) on internal nodes d1, d3, d2, d1b, d3b and d2b at different time periods. The minimum threshold current value imposed on the internal nodes is 40 μA. Similarly, Fig. 12 shows the simulation results of FRTMR latch with transient fault injections on nodes v1 and v2 at different time periods. The minimum threshold current value applied to these nodes is 60 μA. From Fig. 11 and Fig. 12, it can be observed that transient fault at any internal node (except v2) can be 100% tolerable since the output node Q constantly remains at correct value. In case of node v2, the output produces glitch and the glitch remains until the transient fault dies down.

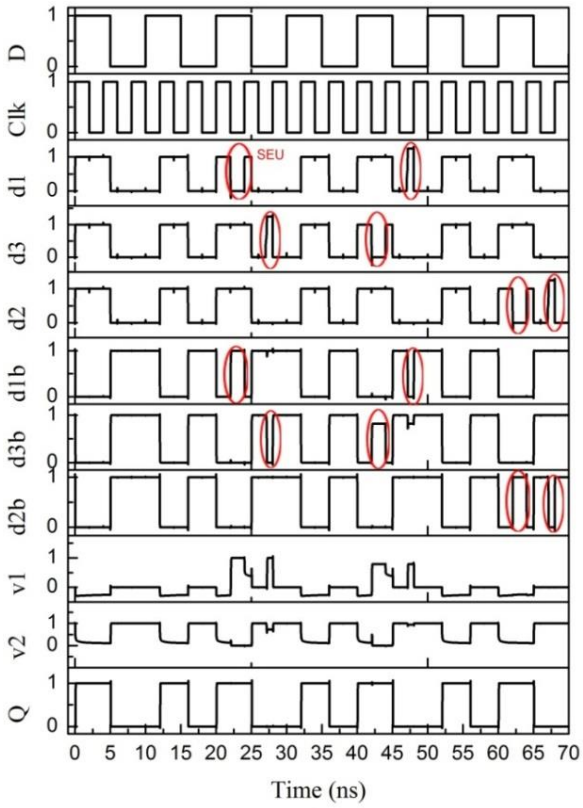

Fig. 11. Simulation Results of FRTMR latch without and with Transient Fault Injections at d1, d3, d2 for D = 0 & 1.

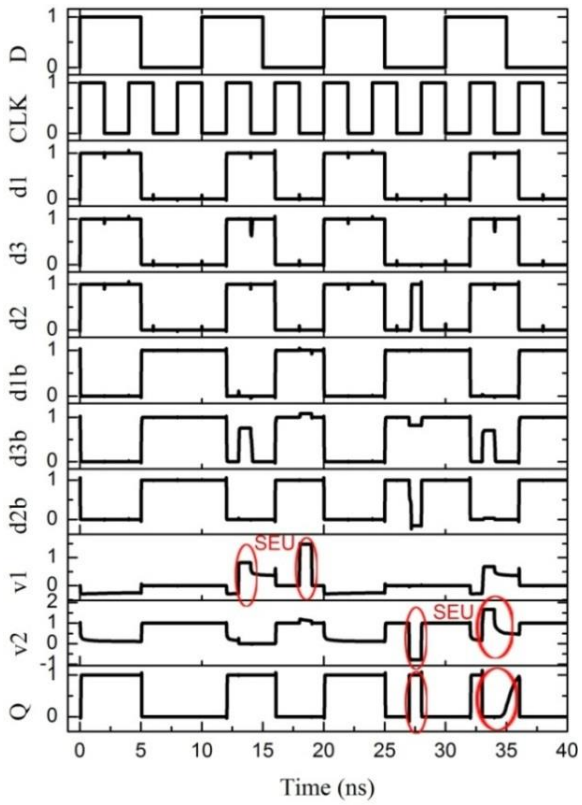

Fig. 12. Simulation Results of FRTMR latch with Transient Fault Injections at v1 and v2 for D = 0 and 1.

From Fig. 11 and Fig. 12, statistics results for the SETs at internal nodes of FRTMR latch design are extracted and presented in Table I. According to Table I, for D = 1, transient fault is injected at 22 ns on node d1. It can be observed that the change in node voltage from 1 → 0, changes d1b from 0 → 1. Although, the output remains correct. Likewise, it is true for the other cases too. Table I also shows the statistics results for D = 1. From the Table I it can be observed that result "SR" denotes as "self-recoverable" nodes, where the output can completely self-recovered from any single node transient injection. Similarly "CN" as "critical nodes" where these nodes can flip the output node voltage and remains until the transient fault injection is removed from that node.

The detailed behaviour of FRTMR latch at internal nodes (d1, d3, d2, d1b, d3b, d2b, v1 and v2) for the data inputs D = 0 & 1 is presented in Table II. Transient fault occurrence to the nodes is highlighted in the table.

A. Multiple Event Transient Analysis of FRTMR Latch

This section elaborates the multi-node upset tolerance analysis of the FRTMR latch. Multiple Event Transients (METs) may occur due to packing density or single events cause multiple transients. However, TMR circuits are only immune to SETs that effect to a single redundancy. Multiple SETs that affect multiple redundancies causes functional failure. Our definition of multi-node in this paper is a node on any one of the redundant latch and node v1 of voter circuit. Node v2 is not considering for multi node upsets as this is a critical node.

MET on <d1, v1>: d1 flip from 0 → 1 and d1b from 1 → 0, the nMOS transistor NV1 is ON and hence v1= 0. On the other hand, since v1 is also affected by transient fault simultaneously, it becomes 1. Thus, v2 = 1. Hence, output Q retains its correct value i.e., Q = 0.

MET on <d3, v1>: d3 flip from 0 → 1 and d3b from 1 → 0, the pMOS transistor PV1 is ON and hence, v1= 1. On the other hand, due to transient fault at v1simultaneously, v1 also tries to become 1. This makes v2 = 1. Hence, output Q retains its correct value i.e., Q = 0.

MET on <d2, v1>: d2 flip from 0 → 1 and d2b from 1 → 0, the nMOS transistor NV1 is ON and hence, v1 = 0. But, due to transient fault at v1, it becomes 1 straight away. This makes v2 = 0. Resulting a wrong data stored at the output i.e., Q = 1. As discussed in the section II, this pair of node is treated as critical node.

Similarly, in the case of 1 being stored, it can be found through an examination that the MET on <d1, v1> and <d1, v1> are 100% self-recoverable, whereas MET on <d2, v1> produces the wrong output. Fig. 13 shows the simulation results of METs of FRTMR latch for data inputs 0 and 1. From Fig. 13, statistics results for the METs at internal node pairs discussed above of FRTMR latch design are extracted and presented in Table III.

TABLE. I. STATISTICS RESULTS OF SET INJECTION OF FRTMRLATCH BASED ON FIG. 11 & 12 (FOR D = 1 & 0)

Time (ns)	Node	(D = 1) Output	Result	Time (ns)	Node	(D = 0) Output	Result
22	d1	Q = 1	SR	47	d1	Q = 0	SR
42	d3	Q = 1	SR	27	d3	Q = 0	SR
62	d2	Q = 1	SR	67	d2	Q = 0	SR
73	v1	Q = 1	SR	93	v1	Q = 0	SR
87	v2	Q = 0	CN	97	v2	Q = 1	CN

TABLE. II. SEU ANALYSIS ON INTERNAL NODES WITH DATA INPUT (D = 0 & 1)

Input (D)	d1	d3	d2	d1b	d3b	d2b	v1	v2	Output (Q)
0	0	0	0	1	1	1	0	1	0 (without SEU)
0	**1**	0	0	0	1	1	1	1	√
0	0	**1**	0	1	0	1	1	1	√
0	0	0	**1**	1	1	0	0	1	√
0	0	0	0	1	1	1	**1**	1	√
0	0	0	0	1	1	1	0	**0**	×
1	1	1	1	0	0	0	0	0	1 (without SEU)
1	**0**	1	1	1	0	0	1	0	√
1	1	**0**	1	0	1	0	1	0	√
1	1	1	**0**	0	0	1	0	0	√
1	1	1	1	0	1	0	**1**	0	√
1	1	1	0	0	0	0	0	**1**	×

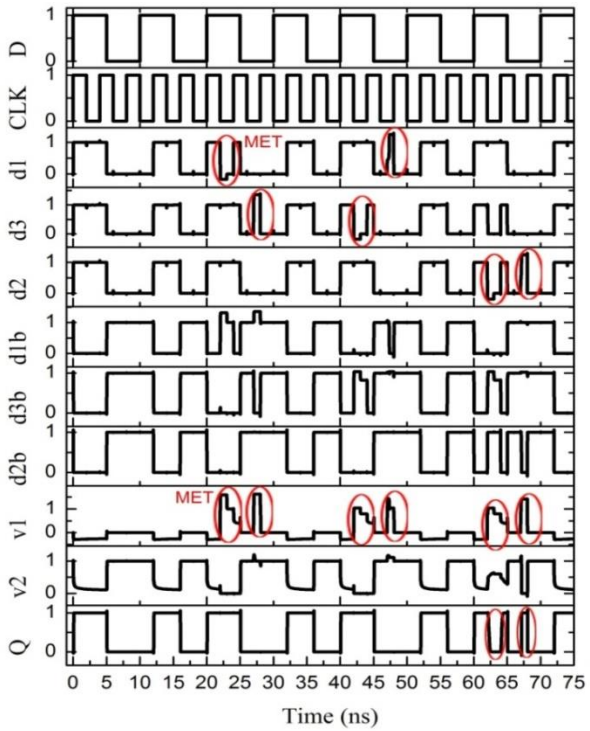

Fig. 13. Simulation Results of MET Injections of the FRTMR Latch for D=0 and 1.

TABLE. III. STATISTICS RESULTS OF MET INJECTION OF FRTMR LATCH BASED ON FIG. 13 (FOR D = 1 & 0)

Time (ns)	Node	Output (D = 1)	Result	Time (ns)	Node	Output (D=0)	Result
22	<d1,v1>	Q = 1	SR	47	<d1,v1>	Q = 0	SR
42	<d3,v1>	Q = 1	SR	27	<d3,v1>	Q = 0	SR
62	<d2,v1>	Q = 0	CN	67	<d2,v1>	Q = 1	CN

SR=Self Recoverable; CN=Critical Node

B. Novel Majority Voter Circuit

Majority voter circuit plays a vital role in TMR design. In TMR circuits, voter circuits are placed around redundant latches to continuously monitor the three logic redundancies. When an SET occurs on any one of the three redundancies, these voter circuits prevent the latches from permanent failure of the logic. The output expression of a transistor level majority voter circuit from Fig. 8 can be derived as:

$$((A \times B) + (B \times C) + (C \times A))' \quad (1)$$

As per the discussion in section II, the disadvantage of the majority voter circuit is, it has more number of critical nodes (n1-n5) i.e., 5 critical nodes. The critical nodes are inversely proportional to reliability. This paper proposes a novel majority voter circuit with only 2 internal nodes out of which, 1 is signified as self-recoverable node and the other is signified as critical node. Equation (2), (3) and (4) are derived at internal nodes v1, v2 and Q of majority voter circuit shown in Fig. 9(b).

$$V1 = d1b \oplus d3b \quad (2)$$

$$V2 = [(d1b \times d3b) + d2b(d1b \oplus d3b)] \quad (3)$$

$$Q = [(d1b \times d3b) + d2b(d1b \oplus d3b)]' \quad (4)$$

IV. PERFORMANCE EVALUATION AND COMPARISON

A classical TMR latch shown in Fig. 8 is considered as reference latch as this circuit is also used a voter circuit for hardening technique. To examine the performance of FRTMR latch, delay (D → Q), power, area, PDP and critical nodes are considered. For the purpose of comparison, the proposed FRTMR latch and existing latches, namely, LCHR, REFL, Latch in [9], [10], [11] and classical TMR Latch are implemented in 45 nm technology with the supply voltage of 1V and 250MHz clock frequency. The implemented latches are simulated in Cadence spectre environment. Table IV compares the evaluation costs for the FRTMR and existing latches with regard to delay, power, PDP, area, critical nodes, etc. From the Table IV, it may be noted that the power consumption of FRTMR latch is 85%, 44.3%, 88% and 17.83% reduced compared to LCHR, Latch in [9], Latch in [10] and classical TMR latch. And also it is third lowest compared with the latches reported in the Table IV. FRTMR latch has 13.8%, 18.4% and 13.88% reduction in area when compared to LCHR, Latch in [10] and classical TMR latch. But it has a trade-off in delay compared to reference latch. It is only best to LCHR latch. Nevertheless, FRTMR latch is more robust for SETs because of the less number of critical nodes (only 1). The proposed FRTMR latch can tolerate multi-node upsets compared to all the latches reported in Table IV.

TABLE. IV. PERFORMANCE COMPARISONS

	Delay (ps)	Power (nW)	PDP (fJ)	Area (# of transistors)	# of Critical nodes	MET tolerant (Yes/ No)
LCHR in [7]	118.7	4880	580	36	7	No
REFL in [8]	67	490	33	26	7	No
Latch in [9]	26.38	1273	33.6	20	-	No
Latch in [10]	73	6077	444	38	11	No
Latch in [11]	3.99	211.3	0.841	16	2	No
Classical TMR latch	48.16	863	41.6	36	5	No
FRTMR latch	66.76	709.09	47.34	31	1	Yes

V. CONCLUSION

At deep sub-micron technology, the CMOS integrated circuits are more likely to experience the occurrence of SETs and METs. This paper proposed FRTMR latch with novel majority voter circuit in 45 nm technology which can tolerate single and multi-node upsets. Generally, the TMR structures consume large silicon area and high power consumption. But,

the proposed FRTMR latch offers, low power and less area i.e. 17.83% and 13.88% respectively compared to existing classical TMR latch. The simulation results demonstrate that the FRTMR latch has 80% improved SEU tolerance than the classical TMR latch. Nonetheless, it has a tradeoff in delay i.e., 38.6% more delay compared to classical TMR latch.

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Efficient Algorithm for Maximal Clique Size Evaluation

Broad Learning of its Relation with Centrality Metrics for Large Dataset Networks

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***Abstract*—A large dataset network is considered for computation of maximal clique size (MC). Additionally, its link with popular centrality metrics to decrease uncertainty and complexity and for finding influential points of any network has also been investigated. Previous studies focus on centrality metrics like degree centrality (DC), closeness centrality (CC), betweenness centrality (BC) and Eigenvector centrality (EVC) and compare them with maximal clique size however, in this study Katz centrality measure is also considered and shows a pretty robust relation with maximal clique size (MC). Secondly, maximal clique size (MC) algorithm is also revised for network analysis to avoid complexity in computation. Association between MC and five centrality metrics has been evaluated through recognized methods that are Pearson's correlation coefficient (PCC), Spearman's correlation coefficient (SCC) and Kendall's correlation coefficient (KCC). The strong strength of association between them is seen through all three correlation coefficients measure.**

Keywords*—Centrality measures; network analysis; maximal clique size

I. Introduction

This Network analysis has become a crucial tool in studying the patterns involved in branched systems and graphs. From its initial journey of solving bridges by Euler all the way back in 1735, network analysis and graph theory have greatly evolved and found applications in nearly every area of study. Since, these analyses involving the exchange of information/resources between 'actors' (nodes) fields like big data science, health care, finance, computer science, social sciences, etc. have grown as a result of efficient use of networking techniques [1].

More specifically Complex Network Analysis has emerged as a major area of research in big data science. The aim of this approach is to analyze real life complex network models using the approaches of graph theory. Numerous approaches have been developed for the analysis of networks; centrality measures have really contributed to the understanding of these networks. Node centrality is a prominently used measure, it links one node with others in the network based on a statistical quantitative measuring of the topological importance of the node with respect to the others [2]. In general, node centrality can help study a wide range of measures ranging from sports associated patterns of play, to identify user preferences in social networks, the most used clinics in urban and rural settings, to even the super-spreaders of a disease, etc. The existing techniques for evaluating the centrality measures involve a neighborhood-based approach and a shortest path algorithm approach. The neighborhood approach makes use of the key features of a node such as the degree centrality (DC) and Eigenvector centrality (EVC), while the shortest path approach utilizes the betweenness centrality (BC) and the closeness centrality (CC) measures [3].

Due to being computationally easier to manage, numerous variations (spatial and temporal) of the algorithms for determining centrality metrics have been developed. However, one question associated with centrality of a node is usually the allowable size of a 'clique' for a node. A graph contains a "clique" that is a set of some nodes such that each two different nodes are adjacent. The size of a clique is defined as the count of nodes that are present in the clique. Every node of a graph might be a piece of one or more than one cliques of different sizes. In networks which are highly linked and have complex interactions, this maximum size of a clique can help identify whether a node in particular is of importance in a community or not based on its modular score. The modularity score is a measure of effectiveness of a networks partitioning into communities. A larger modularity score means a highly inter related community with a high number of vertices within it. Hence, it becomes imperative to identify the vertices that are scored high on the modular scale and design algorithms for the detection of a community using these vertices [2].

The paper is oriented as follows: literature review on network analysis is mentioned in Section II. Section III of this paper contains network analysis through centrality metrics. Revised maximal clique size algorithm evaluation for small network was done in Section IV. Results of centrality metrics and maximal clique size for large product network data is discussed in Section V. Conclusion and future work is presented in Section VI.

II. Literature Review

Stattner and Vidot (2011) presented new favorable circumstances in the area of social networks to comprehend the outbreak of infectious diseases as these events have been increasing rapidly such as the spread of H1N1 influenza virus. Hence the hindrance and regulation of outbreaks have become a health problem of fundamental importance. In this study, the methods already used in epidemiology and those which are recent both are focused in order to apply modeling on disease spreads and overviewed possible future implementations on social network analysis [2].

Zhnag et al. (2015) highlighted the point that common models such as SIR model overlooks the flocking or protection consequences and thus may have some improbable assumptions. Therefore, in this study an improved SIR model is proposed in which these consequences are considered. Both stochastic as well as deterministic models are used to identify the outbreaks on social networks. The results obtained from both of the simulations show that diseases spread even more in social contact networks having greater average of degree. Some dormant immunization strategies have been presented in this work as well to support the findings [3].

Lawyer (2015) mentioned that the spreading power of all nodes in a network should be identified as every vertex in a network generates some force for the distribution of infection, and the recently used centrality measures like eigenvalue, degree or k-shell centrality can be used to accurately identify the nodes that are most influential but not for the nodes that are not much influential. It was concluded that the resulted metric and expected force accurately evaluates the spreading power of all nodes in social contact networks. The force may be estimated independently for each vertex that may be applicable for networks with dynamic or very large adjacency matrix [4].

Yin et al. (2017) proposed a modified SIS model, which contains the property that in social contact networks a vertex along with its neighbor nodes also contacts to the other ones randomly that do not have direct connections that may be called as stranger contacts. This modified model is implemented on a scale-free network and the impact of these different contact patterns are studied on the dynamics of epidemics. This study concluded that the more partiality for direct contacts, the less likely would be the outbreak of disease. Furthermore, the finest strategy of disease control is to adjust both of the number of contact patterns [5].

Meghanathan (2017) explained betweenness centrality metric for complex graphs. Association among betweenness and Local clustering coefficient was discussed. Local clustering coefficient- based degree centrality measure was stated and studied with betweenness centrality on real-world datasets [6].

Meghanathan (2018) identified the relationship among vital centrality measures that are easily computed and maximal clique size which is complex in computation. The association was studied on 10 real-world datasets between centrality metrics and maximal clique size through three well known correlation coefficients that are Pearson's, Spearman's and Kendall's [2].

III. Network Graph and Important Metrics in Network Analysis

Key nodes can be recognized in a given social network by looking forward to the following metrics:

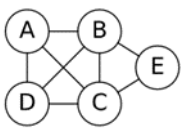

Fig. 1. Undirected Network of 5 Nodes [7].

Adjacency matrix (Ad) for the undirected network containing 5 vertices (nodes) of Fig. 1 is demonstrated as:

$$Ad = \begin{bmatrix} 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 \end{bmatrix} \quad (1)$$

A. Degree Centrality (DC)

Degree Centrality (DC) is a parameter to measure number of contacts that a node have in a graph or a network, contacts are represented by edges. If the communication (edges) is directed among nodes in a graph or a network then the DC is divided into two terminologies that are indegree centrality or outdegree centrality. Indegree and outdegree centrality of a node refers to forward and backward connection towards other nodes present in a network [1].

Degree centrality (DC) measure of network graph present in Fig. 1 is like that node id E minimum value of DC that is 3 whereas node ids B and C have maximum value of DC that is 4 [1].

B. Betweenness Centrality (BC)

The betweenness centrality (BC) of a node is the total count of shortest walks passing through a node among any two nodes by seeing all sets of nodes in the graph. The count of shortest walks from node **m** to node **n** that is passing through a node g (represented as $\boldsymbol{sw_{mn}(g)}$) is the maximum of the count of shortest walks from node **m** to node $\boldsymbol{g}$ in the shortest walk tree rooted at node **m** and the count of shortest walks from node **n** to node $\boldsymbol{g}$ in the shortest walk tree rooted at node **n**. The formula for computation of BC is given by equation (2) and computation of BC for Fig. 1 is mentioned in Table I [2].

$$BC(g) = \sum_{\substack{g \neq m \\ g \neq n}} \frac{sw_{mn}(g)}{sw_{mn}} \quad (2)$$

The equation (2) can compute a betweenness centrality (BC) of a node in any network graph. BC determines the influence of a node in a graph for network analysis in a way that how important a node (vertex) is in between a communication of any other two nodes of the same graph.

From Fig. 1, it is observed clearly that node B and node C are pretty important for communication as they are lying on shortest walk between node A and node E and similarly between node D and node E. Table I demonstrate a fine picture of BC measure.

TABLE. I. BC Measure For a Network in Fig. 1

Node Id A	**Node Id B**	**Node Id C**	**Node Id D**	**Node Id E**
BC of node id A is **0.**	Set$[A,E] \rightarrow 1/2$ Set$[E,A] \rightarrow 1/2$ Set$[D,E] \rightarrow 1/2$ Set$[E,D] \rightarrow 1/2$ BC of node id B is sum of all above sets that is equal to 2.	Set$[A,E] \rightarrow 1/2$ Set$[E,A] \rightarrow 1/2$ Set$[D,E] \rightarrow 1/2$ Set$[E,D] \rightarrow 1/2$ BC of node id B is sum of all above sets that is equal to 2.	BC of node id D is **0.**	BC of node id E is **0.**

C. Closeness Centrality (CC)

Node's closeness centrality (CC) is defined as the reciprocal of the sum of the count of shortest walks from a node to all other nodes present in a network [8]. The formula for CC is given by equation (3) for network analysis. The node which carries a largest amount of CC is nearest to rest of the nodes in a network that aids a node in communicating and developing a relation with other nodes in that graph. Similarly a node with lowest CC is far from other nodes present in a network and that node may face difficulty in communicating and developing a relation with the rest of the nodes in a graph.

$$cc = \frac{1}{\sum count\ of\ shortest\ walks\ between\ a\ node\ to\ all\ other\ nodes} \quad (3)$$

For computation of CC by equation (3), we have to first evaluate shortest walk between every two nodes in a graph. For Fig. 1 shortest walk between every two nodes is represented by shortest walk distance matrix (SWDM) in equation (4).

$$SWDM = \begin{bmatrix} 0 & 1 & 1 & 1 & 2 \\ 1 & 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 2 \\ 2 & 1 & 1 & 2 & 0 \end{bmatrix} \quad (4)$$

It is seen in Fig. 1 that there is no loop present therefore diagonal element of SWDM are zero shown in equation (4). Sum of shortest walk for each node is represented in equation (5).

$$\sum SWDM = \begin{bmatrix} 5 \\ 4 \\ 4 \\ 5 \\ 6 \end{bmatrix} \quad (5)$$

Finally CC for each node i in Fig. 1 is computed in equation (6) by following the definition of CC measure.

$$CC(i) = \frac{1}{\sum SWDM(i)} = \begin{bmatrix} 0.200 \\ 0.250 \\ 0.250 \\ 0.200 \\ 0.167 \end{bmatrix} \quad (6)$$

Outcomes in equation (6) shows the significance of node B and node C that have highest amount of CC which means node B and node C are nearest to rest of the nodes in a graph presented in Fig. 1.

D. Eigenvector Centrality (EVC)

Eigenvector centrality (EVC) is a measurement of amount that indicates key nodes in a graph. EVC explains the role of neighboring nodes in a way that all those nodes are essential in a network which are linked with useful nodes. Dominant eigenvector of adjacency matrix (Ad) is EVC. The EVC amount of the nodes in a network corresponds to the input for the nodes in the principal eigenvector of the network represented by $\boldsymbol{Ad}$. The **n** eigenvalues and the corresponding eigenvector is extracted from **n×n** Ad. Power method is used for evaluation of EVC from $\boldsymbol{Ad}$ of the network. For this method, we initiate from the ones vector that is $\boldsymbol{X_o} = [\mathbf{1\ 1\ 1} \ldots . \mathbf{1\ 1\ 1}]$ corresponding to the count of nodes in the network and passes through a number of iterations [2, 9, 10]. The preliminary eigenvector evaluated during the$(k+1)^{th}$ iteration is given as follows:

$$EVC = \frac{(Ad)*X_k}{\|(Ad)*X_k\|} \quad (7)$$

Where $\|(Ad) * X_k\|$ is the normalized amount of the EVC obtained in proceeding of k^{th}iteration. Power method is applied and repeated till normalized values becomes same and converges as seen in Table II.

Table II also points the importance of node id B and node id C in the considered graph network (that is Fig. 1). In 7th iteration of power method we obtained a dominant eigenvalue and corresponding eigenvector for a matrix graph Ad.

E. Katz Centrality (KC)

The Katz centrality (KC) evaluates the centrality of a vertex (node) that depends on the centrality of its adjacent nodes relatively than considering shortest walks between nodes. It is a broad view of EVC [11]. The Katz centrality (KC) for node $\boldsymbol{g}$ is computed by formula mentioned in equation (8).

$$KC(g) = \alpha \sum_{j=1}^{n} Ad_{ji} KC(g) + \beta \quad (8)$$

Where, the parameter $\boldsymbol{\beta}$ controls the centrality not to become zero. First term of equation (8) arrows to eigenvector centrality (EVC).

$$KC = \alpha Ad^T KC + \beta.\mathbb{I} \quad (9)$$

In equation (9), $\mathbb{I}$ is a unit column vector.

$$KC - \alpha Ad^T KC = \beta.\mathbb{I} \quad (10)$$

$$KC(1 - \alpha Ad^T) = \beta.\mathbb{I} \quad (11)$$

$$KC = \beta(1 - \alpha Ad^T)^{-1}.\mathbb{I} \quad (12)$$

For computation of Katz centrality (KC), always suppose value of alpha (α) less than the reciprocal of dominant eigenvalue (λ) for convergence. As dominant eigenvalue is obtained for network presented in Fig. 3 is of amount **3.3234;** therefore, in equation (12) considering $\alpha = 0.2$ and $\beta = 1$ for Katz centrality (KC) computation. Equation (13), (14), (15) and (16) demonstrated the complete evaluation details of Katz centrality for a network in Fig. 1.

$$KC = 1 \times \left(\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} - 0.2 \begin{bmatrix} 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 \end{bmatrix} \right)^{-1} \times \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} \quad (13)$$

$$KC = \left(\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} - \begin{bmatrix} 0.0 & 0.2 & 0.2 & 0.2 & 0.0 \\ 0.2 & 0.0 & 0.2 & 0.2 & 0.2 \\ 0.2 & 0.2 & 0.0 & 0.2 & 0.2 \\ 0.2 & 0.2 & 0.2 & 0.0 & 0.0 \\ 0.0 & 0.2 & 0.2 & 0.0 & 0.0 \end{bmatrix} \right)^{-1} \times \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} \quad (14)$$

$$KC = \left(\begin{bmatrix} 1.00 & -0.2 & -0.2 & -0.2 & 0.00 \\ -0.2 & 1.00 & -0.2 & -0.2 & -0.2 \\ -0.2 & -0.2 & 1.00 & -0.2 & -0.2 \\ -0.2 & -0.2 & -0.2 & 1.00 & 0.00 \\ 0.00 & -0.2 & -0.2 & 0.00 & 1.00 \end{bmatrix} \right)^{-1} \times \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} \quad (15)$$

TABLE. II. EVC MEASURE FOR A NETWORK IN FIG. 1

$$EV1 = \begin{bmatrix} 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 3 \\ 4 \\ 4 \\ 3 \\ 2 \end{bmatrix}$$

$$Normalized\ value = n1 = \sqrt{3^2 + 4^2 + 4^2 + 3^2 + 2^2} = 7.3485$$

$$EVC1 = \frac{EV1}{n1} = \begin{bmatrix} 0.4082 \\ 0.5443 \\ 0.5443 \\ 0.4082 \\ 0.2722 \end{bmatrix} \rightarrow Iteration\ \#\ 1$$

$$EV2 = \begin{bmatrix} 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0.4082 \\ 0.5443 \\ 0.5443 \\ 0.4082 \\ 0.2722 \end{bmatrix} = \begin{bmatrix} 1.4969 \\ 1.6330 \\ 1.6330 \\ 1.4969 \\ 1.0887 \end{bmatrix}$$

$$n2 = \sqrt{1.4969^2 + 1.6330^2 + 1.6330^2 + 1.4969^2 + 1.0887^2} = 3.3166$$

$$EVC2 = \frac{EV2}{n2} = \begin{bmatrix} 0.4513 \\ 0.4924 \\ 0.4924 \\ 0.4513 \\ 0.3282 \end{bmatrix} \rightarrow Iteration\ \#\ 2$$

$$EV4 = \begin{bmatrix} 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0.4323 \\ 0.5188 \\ 0.5188 \\ 0.4323 \\ 0.2965 \end{bmatrix} = \begin{bmatrix} 1.4699 \\ 1.6799 \\ 1.6799 \\ 1.4699 \\ 1.0376 \end{bmatrix}$$

$$n4 = \sqrt{1.4699^2 + 1.6799^2 + 1.6799^2 + 1.4699^2 + 1.0376^2} = 3.3230$$

$$EVC4 = \frac{EV4}{n4} = \begin{bmatrix} 0.4424 \\ 0.5055 \\ 0.5055 \\ 0.4424 \\ 0.3122 \end{bmatrix} \rightarrow Iteration\ \#\ 4$$

$$EV5 = \begin{bmatrix} 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0.4424 \\ 0.5055 \\ 0.5055 \\ 0.4424 \\ 0.3122 \end{bmatrix} = \begin{bmatrix} 1.4534 \\ 1.7025 \\ 1.7025 \\ 1.4534 \\ 1.0111 \end{bmatrix}$$

$$n5 = \sqrt{1.4534^2 + 1.7025^2 + 1.7025^2 + 1.4534^2 + 1.0111^2} = 3.3233$$

$$EVC5 = \frac{EV5}{n5} = \begin{bmatrix} 0.4373 \\ 0.5123 \\ 0.5123 \\ 0.4373 \\ 0.3042 \end{bmatrix} \rightarrow Iteration\ \#\ 5$$

$$EV7 = \begin{bmatrix} 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0.4399 \\ 0.5089 \\ 0.5089 \\ 0.4399 \\ 0.3083 \end{bmatrix} = \begin{bmatrix} 1.3442 \\ 1.0972 \\ 1.0972 \\ 0.7531 \\ 0.3482 \end{bmatrix}$$

$$n7 = \sqrt{1.3442^2 + 1.0972^2 + 1.0972^2 + 0.7531^2 + 0.3482^2} = 3.3234 \rightarrow \lambda\ (Principal\ Eigenvalue)$$

$$EVC7 = \frac{EV7}{n7} = \begin{bmatrix} 0.4386 \\ 0.5106 \\ 0.5106 \\ 0.4386 \\ 0.3062 \end{bmatrix} \rightarrow Iteration\ \#\ 7$$

$$KC = \begin{bmatrix} 1.2821 & 0.4808 & 0.4808 & 0.4487 & 0.1923 \\ 0.4808 & 1.3782 & 0.5449 & 0.4808 & 0.3846 \\ 0.4808 & 0.5449 & 1.3782 & 0.4808 & 0.3846 \\ 0.4487 & 0.4808 & 0.4808 & 1.2821 & 0.1923 \\ 0.1923 & 0.3846 & 0.3846 & 0.1923 & 1.1538 \end{bmatrix} \times \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} \quad (16)$$

$$KC = \begin{bmatrix} 2.8846 \\ 3.2692 \\ 3.2692 \\ 2.8846 \\ 2.3077 \end{bmatrix} \quad (17)$$

Equation (17) also arrows a same result of influential nodes in a network as all four previous centrality measure indicates that node id B and node id C plays a vital role in communication and developing relation with other remaining nodes. Now we move towards Section IV for a concept of maximal clique size (MC) evaluation and its connection with centrality metrics.

IV. MAXIMAL CLIQUE SIZE (MC) AND ITS ASSOCIATION WITH KEY CENTRALITY METRICS

The concept behind maximal clique size (MC) of a graph for any node is that the node $\boldsymbol{g}$ is assigned a value that belongs to the presence of node $\boldsymbol{g}$ in a maximum clique size (MC) of that graph. The MC of a node is a determination of amount of modularity of a node and that can be used to recognize seed nodes about which communities can develop. The evaluation of modular node in large dataset networks have very significance for network analysis but it is seen from previous literature that preference was given to linked measure called maximal clique size (MC) over count of modular nodes. In addition to previous work, we modify previous methods for determination of maximal clique size (MC) for large dataset networks which was pretty difficult to compute, aim is to decrease complexity in computation. Modified algorithm of MC is mentioned in Table IX. Also small network example (that is Fig. 1) is considered to explain the concept of MC.

There are in total two maximal cliques present that are demonstrated in Fig. 2 with two different colors. One maximal clique is {A, B, C, D} shown by yellow lines and second one is {B, C, E} shown by green color. MC value for each node is represented in Table III.

The link between maximal clique size (MC) and all five centrality metrics is measured through renowned correlation coefficients that are Pearson's, Spearman's and Kendall's which are discussed briefly and determined in this section. The association between MC and all five centrality metrics is important in the way that if strength of association is strong and positive then we can go for centrality metrics in network analysis rather than to compute MC. Results has shown strength of positive association between them which are mentioned in Table XV.

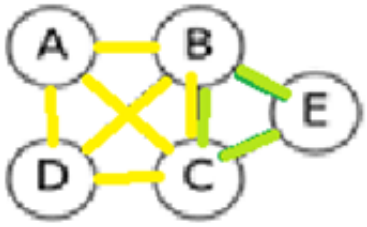

Fig. 2. Marking of Maximal Cliques on a Network Considered in Fig. 1.

TABLE. III. MAXIMAL CLIQUE SIZE FOR A NETWORK IN FIG. 1

Node ID	A	B	C	D	E
MC	4	4	4	4	3

A. Pearson's Product Moment-Based Correlation Coefficient (PCC)

The Pearson's correlation coefficient (PCC) is stated for any two data's as the ratio of covariance and the product of standard deviations. Suppose mean of maximal clique size and degree centrality are demonstrated by $\boldsymbol{MC_{avg}}$ and $\boldsymbol{DC_{avg}}$respectively for a network of **n** number of nodes. Suppose that each input corresponding to **n** number of nodes for maximal clique size and degree centrality is demonstrated by $\boldsymbol{MC_i}$ **and** $\boldsymbol{DC_i}$ respectively [6]. The evaluation for Fig. 1 through equation (18) is computed in Table IV.

$$PCC(MC,DC) = \frac{\sum_{i=1}^{n}(MC_i - MC_{avg})(DC_i - DC_{avg})}{\sqrt{\sum_{i=1}^{n}(MC_i - MC_{avg})^2 \sum_{i=1}^{n}(DC_i - DC_{avg})^2}} \quad (18)$$

$$PCC(MC,DC) = \frac{1.2}{\sqrt{0.8 \times 2.8}} = 0.8017 \quad (19)$$

From equation (19) it is clear that there exists a pretty strong positive association between maximal clique size (MC) and degree centrality (DC) that is of amount **0.8017**. The outcome indicates that for recognition of influential nodes in a network analysis one may use degree centrality metric (DC) as compared to maximal clique size (MC) that is difficult and time consuming to evaluate. Now we move on to other method of finding link between these two measures that is Spearman's correlation coefficient.

B. Spearman's Rank-Based Correlation Coefficient (SCC)

The Spearman's correlation coefficient (SCC) is stated for two data's as the determination of association by considering the ranks of the values rather than their exact values. To find the link between two variables MC and DC, we transform the two data's $\boldsymbol{MC_i}$ **and** $\boldsymbol{DC_i}$into rank data that is $\boldsymbol{m_i}$ **and** $\boldsymbol{dc_i}$ respectively. SSC can be evaluate through formula presented in equation (20) [6].

$$SCC(MC,DC) = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n(n^2-1)} \quad (20)$$

Where, $d_{i=}m_i - dc_i$ is the difference of ranks between two variables. The evaluation of SCC between MC and DC for network in Fig. 1 is done through equation (20) presented in Table V.

$$SCC(MC,DC) = 1 - \frac{6*4}{5(5^2-1)} = 1 - \frac{24}{120} = 0.8 \quad (21)$$

Equation (21) demonstrates the output of SCC computation that also shows a pretty strong positive association between MC and DC that is of amount **0.8**. In few words, one may prefer DC over MC evaluation for a network analysis.

C. Kendall's Concordance-based Correlation Coefficient (KCC)

Kendall's correlation coefficient (KCC) is stated for two data's as the count of similarity in the arrangement of the values for the variables (data's) acquired by the nodes in the network. The set of nodes $\boldsymbol{n_i}$ and $\boldsymbol{n_j}$ are said to be concordant sets (conc.sets) if either of these 2 nodes rigorously has a greater value or a smaller value for two variables MC and DC. Similarly, the set of two $\boldsymbol{n_i}$ and $\boldsymbol{n_j}$ is said to be discordant sets (disc.sets) if a node has a greater value or smaller value for at least one out of two variables. The set of nodes $\boldsymbol{n_i}$ and $\boldsymbol{n_j}$ is neither said to be concordant set nor to be discordant set if either of the set have equal values for MC and DC (shown in Table VI) [2]. The KCC is evaluated by formula presented in equation (22) and evaluation is presented in Table VII.

$$KCC(MC,DC) = \frac{no.of\ conc.sets - no.of\ disc.sets}{\frac{1}{2}n(n-1)} \quad (22)$$

$$no.of\ conc.sets = 4 \quad (23)$$

$$no.of\ disc.sets = 0 \quad (24)$$

$$Total\ no.of\ sets = \frac{5(5-1)}{2} = 10 \quad (25)$$

$$KCC(MC,DC) = \frac{4-0}{10} = 0.4 \quad (26)$$

Count of concordant sets (conc.sets) is given by equation (23), count of discordant sets (disc.sets) is given by equation (24) and equation (25) represents the total number of sets. The outcome of the Kendall's correlation coefficient (KCC) is given by equation (26) that arrows positive link between maximal clique size (MC) and degree centrality (DC) that is of amount **0.4**. This amount also shows the preference of degree centrality (DC) over maximal clique size (MC).

TABLE. IV. FINDING ASSOCIATION BETWEEN MC AND DC THROUGH PCC

n_i	MC	DC	$MC - MC_{avg}$	$DC - DC_{avg}$	$(MC - MC_{avg}) * (DC - DC_{avg})$	$(MC - MC_{avg})^2$	$(DC - DC_{avg})^2$
A	4	3	0.2	-0.2	-0.04	0.04	0.04
B	4	4	0.2	0.8	0.16	0.04	0.64
C	4	4	0.2	0.8	0.16	0.04	0.64
D	4	3	0.2	-0.2	-0.04	0.04	0.04
E	3	2	-0.8	-1.2	0.96	0.64	1.44
Avg	3.8	3.2		Sum	1.2	0.8	2.8

TABLE. V. FINDING ASSOCIATION BETWEEN MC AND DC THROUGH SCC

n_i	MC	Trial Rank: MC	Final Rank: m_i	DC	Trial Rank: DC	Final Rank: dc_i	$d_i = m_i - dc_i$	d_i^2
A	4	2	3.5	3	2	2.5	1	1
B	4	3	3.5	4	4	4.5	-1	1
C	4	4	3.5	4	5	4.5	-1	1
D	4	5	3.5	3	3	2.5	1	1
E	3	1	1	2	1	1	0	0
							Sum	4

TABLE. VI. VALUES OF MC AND DC FOR EACH NODE PRESENT IN FIG. 1

Node Id	A	B	C	D	E
MC	4	4	4	4	3
DC	3	4	4	3	2

TABLE. VII. FINDING ASSOCIATION BETWEEN MC AND DC THROUGH KENDALL'S CORRELATION COEFFICIENT

Node Sets (n_i, n_j)	(A, B)	(A, C)	(A, D)	(A, E)	(B, C)	(B, D)	(B, E)	(C, D)	(C, E)	(D, E)
MC_i, DC_i	(4,3)	(4,3)	(4,3)	(4,3)	(4,4)	(4,4)	(4,4)	(4,4)	(4,4)	(4,3)
MC_j, DC_j	(4,4)	(4,4)	(4,3)	(3,2)	(4,4)	(4,3)	(3,2)	(4,3)	(3,2)	(3,2)
Class of Sets	**N/A**	**N/A**	**N/A**	**Conc.set**	**N/A**	**N/A**	**Conc.set**	**N/A**	**Conc.set**	**Conc.set**

V. AMAZON PRODUCT NETWORK DATA

The dataset of amazon product co-purchasing is of June 2003 containing 403394 nodes and 3387388 edges is evaluated. This data informs the consumer's pattern of buying which kind of products are usually bought in combination [12]. This 403394 nodes (products) data is converted into adjacency matrix $'Ad'$ and then graph is formed for further network analysis as demonstrated in Fig. 3 and Fig. 4 where nodes (products) are in blue color and edges are represented by green color.

Amazon co-purchasing data of 1001 products are extracted for computation to identify influential products through centrality metrics. All these five metrics are strongly linked with each other. It is captured in Table VIII clearly like node id 4 is highest in all 5 metrics.

Table VIII shows all five centrality metrics of nodes present in large product data set. Evaluation is done on extracted data of 1001 nodes from amazon website. The target is to find influential nodes through centrality metrics and maximal clique size (MC). Node id **5** is found as vital node (product) in network analysis through these 5 measures, as node id **5** have highest values in all most all 5 measures that indicates its importance in terms of profit in marketing as these outcomes are evaluated through amazon product network data. Secondly node id **29** has a second highest measure which is also arrows its importance in marketing of amazon products. Now we move towards another significant measure in network analysis that is maximum clique size (MC).

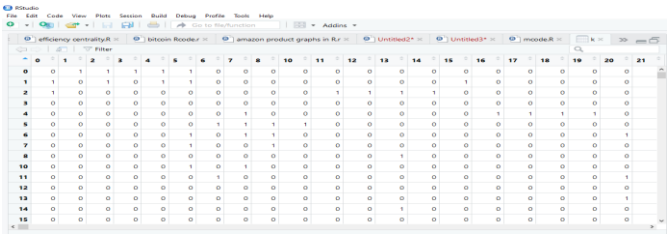

Fig. 3. Adjacency Matrix Formation for Amazon Product Dataset.

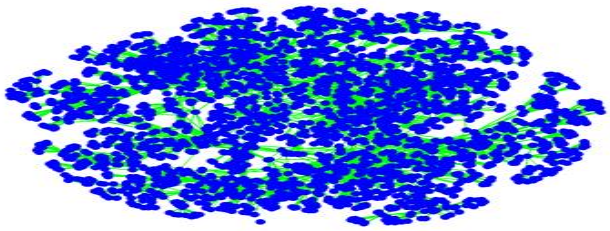

Fig. 4. Plot of Amazon Product Network from Adjacency Matrix.

TABLE. VIII. DETERMINATION OF INFLUENTIAL NODES IN AMAZON DATA THROUGH CENTRALITY METRICS

Products (Nodes Id)	**Degree (DC)**	**Betweenness (BC)**	**Closeness (CC)**	**Eigenvector (EVC)**	**Katz Centrality (KC)**
0	10	452.448	5.1939e-05	0.08630	1.1244
1	10	150.285	4.7123e-05	0.05577	1.1166
2	10	122.528	4.6759e-05	0.07234	1.1190
3	10	1150.530	5.2952e-05	0.08552	1.1272
4	21	9008.548	5.3205e-05	0.17034	1.2619
5	74	311765.340	6.0335e-05	0.5	1.8879
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
29	31	858717.100	5.0241e-05	0.00122	1.3649
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
499	11	563.207	4.7703e-05	0.00068	1.1250
500	10	3816.174	4.7700e-05	0.00067	1.1140
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
999	10	4506.667	3.8430e-05	2.4901e-07	1.0942
1000	10	0	1.2411e-07	1.0142e-17	1.0000

TABLE. IX. PSEUDO-ALGORITHM FOR COMPUTATION OF MAXIMAL CLIQUE SIZE IN LARGE DATASET

```
> Import. Dataset (data)
>A=Adjacency. Matrix (data) #formation of Adjacency matrix from a network data
> Library (ggnet); library (network); library (sna); library (ggplot2)
>graph=network (A)
>g=ggnet2 (graph)
>g=plot (A)          # graph formation
>largest. Cliques (g) # display maximal cliques and nodes that are present in largest clique size
>n=clique. Number (g)                          # node count in maximal clique
>m=maximal. Cliques (g)
>r=zeros (total nodes, 1)                      # null matrix of total nodes by 1
>   if    (n>=1) then
          for    i : total nodes do
                  v= unlist (m[n])
                  display (v)   }
                Nv =length (v)
                for   (i in 1: Nv) do
                         j ←v[i]
                   if    (r[j] <= Nv) then
                           r[j]   ← length (v)
                           display (r)
                                   else   {
                                           display (r)    }   }
                    n=n-1      }  }        # return a vector r of total nodes by 1 dimension containing a maximal clique size for each node
```

The maximal clique size (MC) is evaluated for amazon product network of 1001 nodes by improved algorithm as mentioned in Table IX and outcomes for each node in a network are represented in Table X. This improved algorithm decreases the complexities in computation and demonstrates the appropriate result of MC for each and every node in the data.

The maximal clique size (MC) is evaluated for amazon product network of 1001 nodes that is mentioned in Table X. The association between MC and DC by three renowned measures are discussed and evaluated that are represented in Tables XI, XII, XIII and XIV by correlation coefficients Pearson's, Spearman's and Kendall's, respectively.

$$PCC(MC, DC) = \frac{3313.17}{\sqrt{6228.476 \times 26079.77}} = 0.2599566 \quad (27)$$

The outcome of link between maximal clique size (MC) and degree centrality (DC) through PCC for large dataset of amazon network is equals to **0.2599566** which shows positive association between these two variables as discussed in previous section for small network example.

$$SCC(MC, DC) = 1 - \frac{6*115461200}{1001 \times (1001^2 - 1)} = 0.3093 \quad (28)$$

Similarly, the result of association between maximal clique size (MC) and degree centrality (DC) of amazon product network through SCC measure also indicates a positive link that is of amount **0.3039**. It is also pretty clear from Table XIII that node id 5 which carries all five highest centrality metrics specially highest DC i.e. 74 also contains third larger maximal clique size (MC) in amazon network which shows strength of link between them.

TABLE. X. MAXIMAL CLIQUE SIZE COMPUTATION FOR AMAZON PRODUCT DATA

Node Id	0	1	2	3	4	5	.	499	500	.	999	1000
MC	5	5	5	5	6	8	.	9	9	.	2	2

TABLE. XI. EVALUATING RELATION AMONG MC AND DC FOR AMAZON DATASET THROUGH PCC

n_i	MC	DC	$MC - MC_{avg}$	$DC - DC_{avg}$	$(MC - MC_{avg}) * (DC - DC_{avg})$	$(MC - MC_{avg})^2$	$(DC - DC_{avg})^2$
0	5	10	-0.718	-2.685	1.928	0.515	7.209
1	5	10	-0.718	-2.685	1.928	0.515	7.209
2	5	10	-0.718	-2.685	1.928	0.515	7.209
3	5	10	-0.718	-2.685	1.928	0.515	7.209
4	6	21	0.282	8.315	2.345	0.079	69.139
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
499	9	11	3.282	-1.685	-2.24817	10.771	2.839
500	9	10	3.282	-2.685	-5.53017	10.771	7.209
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
999	2	10	-3.718	-2.685	9.983	13.823	7.209
1000	2	10	-3.718	-2.685	9.983	13.823	7.209
Avg	5.72	12.7		**Sum**	3313.17	6228.476	26079.77

TABLE. XII. EVALUATING RELATION AMONG MC AND DC FOR AMAZON DATASET THROUGH SCC

n_i	MC	Final Rank: m_i	DC	Final Rank: dc_i	$d_i = m_i - dc_i$	d_i^2
0	5	338	10	203	135	18225
1	5	338	10	203	135	18225
2	5	338	10	203	135	18225
3	5	338	10	203	135	18225
4	6	473	21	942	-469	219961
.	.	.	.	.	.	.
.	.	.	.	.	.	.
499	9	924	11	478	446	86142.25
500	9	924	10	203	721	198916.00
.	.	.	.	.	.	.
.	.	.	.	.	.	.
999	2	122	10	203	-81	6561
1000	2	122	10	203	-81	6561
					Sum	115461200

TABLE. XIII. COUNT OF MC AND DC MEASURE FOR EACH NODE IN AMAZON PRODUCT NETWORK

Node Id	0	1	2	3	4	5	.	499	500	.	999	1000
MC	5	5	5	5	6	8	.	9	9	.	2	2
DC	10	10	10	10	21	74	.	11	10	.	10	10

TABLE. XIV. EVALUATING RELATION BETWEEN MC AND DC FOR AMAZON PRODUCT NETWORK

Node Sets (n_i, n_j)	(0,1)	(0,2)	(0,3)	(0,4)	(0,5)	.	(499,500)	.	(999,1000)
MC_i, DC_i	(5,10)	(5,10)	(5,10)	(5,10)	(5,10)	.	(9,11)	.	(2,10)
MC_j, DC_j	(5,10)	(5,10)	(5,10)	(6,21)	(8,74)	.	(9,10)	.	(2,10)
Class of Sets	**N/A**	**N/A**	**N/A**	**Conc.set**	**Conc.set**	**.**	**N/A**	**.**	**N/A**

TABLE. XV. RELATIONSHIP BETWEEN KEY CENTRALITY METRICS AND MC USING PCC, SCC AND KCC

	DC and MC			**BC and MC**			**CC and MC**			**EVC and MC**			**KC and MC**		
	PCC	**SCC**	**KCC**	**PCC**	**SCC**	**KCC**	**PCC**	**SCC**	**KCC**	**PCC**	**SCC**	**KCC**	**PCC**	**SCC**	**KCC**
5 nodes network in Fig. 1	0.801	0.8	0.4	0.408	0.408	0.408	0.721	0.745	0.707	0.904	0.707	0.632	0.873	0.725	0.667
Amazon Product network	0.259	0.309	0.177	0.057	-0.18	-0.13	-0.07	-0.12	-0.082	0.122	0.085	0.065	0.299	0.415	0.301

$$\text{no. of conc. sets} = 214698 \quad (29)$$

$$\text{no. of disc. sets} = 125986 \quad (30)$$

$$Total\ no.of\ sets = \frac{1001(1001-1)}{2} = 500500 \quad (31)$$

$$KCC(MC, DC) = \frac{214698-125986}{500500} = 0.17724 \quad (32)$$

Equation (32) represents the outcome of KCC for maximal clique size (MC) and degree centrality (DC) that again conveys a positive link between them for amazon product data of 1001 nodes. It is observed from previous literature and present study that amount of KCC measure is small as compared to PCC and SCC measures but delivers a same picture of concept that they have positive connection between maximal clique size (MC) and degree centrality (DC) in network analysis.

The bond between fundamental centrality metrics (like DC, BC, CC, EVC and KC) and maximal clique size (MC) is demonstrated in Table XV through PCC, SCC and KCC measures. It is seen that DC, EVC and KC have strong positive relation with MC in network analysis. Katz centrality (KC)

metric also shows pretty strong positive association with maximal clique size (MC) as it is observed from present study. For determination of significant nodes in large datasets one may prefer degree centrality (DC), eigenvector centrality (EVC) and Katz centrality (KC) measures over maximal clique size (MC) computation which is difficult to measure. Secondly, betweenness and closeness centrality metrics shows least association with MC.

VI. Conclusion

The complete work of this paper addressed an amount of modularity and use of improved method of maximal clique size (MC) in large network datasets. Although it is hard to measure MC for big datasets and finding its connection with centrality metrics, the improved algorithm has been introduced to decrease complexity for large networks and results have been computed for Amazon large product network data and also for a small network example. Strong connection of maximal clique size (MC) with degree centrality (DC), eigenvector centrality (EVC) and Katz centrality (KC) was seen by Pearson's correlation (PCC), Spearman's correlation coefficient (SCC) and Kendall's correlation coefficient (KCC). The strength of association between them indicates that these three centrality measures can be favored over maximal clique size (MC) computation for network analysis. It is also seen that Pearson's and Spearman's correlation coefficients measure outcomes are almost same as compared to Kendall's correlation coefficient measure which shows small values in their comparison but picture of outcome is same that is quality of association between variables.

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A Conceptual Smart City Framework for Future Industrial City in Indonesia

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***Abstract*—In Indonesia, the growth of cities from various big cities and industrial cities can cause many challenges. To face this challenge, policy makers can apply the concept of smart cities. This paper aims to analyze many studies that discuss prospective industrial city planning in a smart city perspective. This research uses information from research, models, frameworks, and tools that discuss IoT, smart cities, and industrial cities. This research provides the latest insight into smart city frameworks for industrial cities. In this study found the pillars forming the smart city for industrial cities. This framework can also be used by governments such as Kulonprogo District in the Special Region of Yogyakarta, Indonesia in preparation to transform itself into a smart industrial city. The latest use of information technology in this concept and with implementation priority steps is recommended.**

Keywords*—Smart city; industrial city; smart industrial city; framework; Kulonprogo District

I. Introduction

Cities are complex systems that are characterized by massive numbers of interconnected citizens, businesses, different modes of transportations, communication networks, services and utilities [1]. These cities face many challenges during their development and smart city is believed to be the answer to these challenges. Connecting many residents linking smart transportation needs, facilitating communication, improving government performance, and making some aspects of people's lives "smart" are the embodiment of a smart city. Many cities in Indonesia also face similar challenges.

The development of the cities in Indonesia is very dynamics due to their own unique characteristics. The capital city such as Jakarta is inhabited by government officials, national and multi-national company workers, and travelers. Tourism cities such as Denpasar in Bali, besides being inhabited by indigenous people, are also visited by domestic and foreign tourists. The city of education, such as Yogyakarta is inhabited by visitors who study and they leave when they finish their study. There are also several industrial cities such as Karawang, Surabaya, Cilegon, etc. These industrial cities are existed and developed due to manufacturing industries, and they will eventually become larger industrial cities.

Industries have big impacts for the surrounding environment, especially for the cities in which they reside. Policy makers must prepare an industrial city that cares about the environment, saves electricity, and minimizes the role of workers by optimizing technology. The government must prepare for the arrival of migrants from other cities who work and live in city. Even though this is a busy city with high mobility of the people, local government must have obligations to improve the quality of life of the citizens.

This research is looking for the right framework for cities that are prepared to become industrial cities, and what elements must be met to realize the concept of smart city in an industrial city. As a limitation, this study discusses the appropriate framework for realizing Kulonprogo District as a smart industrial city. Kulonprogo District (kulonprogokab.go.id) is located in western part of the Special Region of Yogyakarta, Indonesia. In the literature review section, the author provides information relating to industrial cities, smart cities, and the application of smart city concepts in industrial cities. Next in this paper will be discussed about smart city architecture and priorities for implementing smart city policies in Kulonprogo as potential industrial cities.

II. Literature Review

A. Industrial City

According to the KBBI (*Kamus Besar Bahasa Indonesia*), an industrial city is a city that is a place of residents who are mostly involved in industrial activities. Therefore, there are aspects of communication and cooperation between all the people within the city. The government, government-owned companies, private companies, investors, workers are stakeholders who are actively involved in urban activities. To support the process of city activities, the industry's main supporting infrastructure must be prepared. The government prepares the city vision, regulations, physical infrastructures, and creates favorable investment climate. When there is a clear vision, legal certainty, well-prepared physical infrastructures, the investment climate will grow significantly in which investors will come to invest. The use of the latest technology for the development of industrial cities is also important to improve the quality and quantity of production.

In the last few years a concept of Industry 4.0 has developed. This concept holds the promise of increased flexibility, mass customization, increased speed, improved quality, and enhanced productivity in manufacturing and thus enabling companies with various challenges, such as increasingly individualized products, shortened leads time to market, and high product quality [2]. The eight planning to enable the concept are: standardization of systems and building a references architecture; efficient management, establishment a comprehensive and reliable industrial

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broadband infrastructure; safety and security, organization and design of works; staff training and continuing professional development; establishing a regulatory framework in improving of the efficiency of resource use.

B. Smart City

There are many interpretations of smart city by researchers, and they mostly focus on three interpretations. Table I shows some papers with their interpretations of smart city.

Table I shows several studies regarding three differences in the focus of smart city. The first focus is smart city which emphasizes the best and latest technology to be applied to a city. The second focus is the population who are already aware of the use of technology, so they design a city by placing technology to help solve their problems. The third focus is the combination of the previous focuses, which are technological advancements are complementary to the desires of city residents in creating a smart city.

C. Smart City Characteristics

There are four smart city components, namely: smart infrastructure, smart operations, smart services and smart industries. Moreover, smart city has four basic characteristics [8]:

- Interconnection between parties in the city: smart cities will integrate means of communication, sensors, internet and support to facilitate, accelerate communication without obstacles [9][10].
- Integration of urban information systems: The Internet and cloud computing are used in all aspects of city life.
- Management of government services and urban services to provide the best service.
- Technology applications, especially the latest ICT: smart cities use modern city management as a guide, emphasizing the application of information technology into city management and inspiring all government agencies, companies, and people to make innovations, urban development movements

TABLE I. SMART CITIES DEFINITION

Smart City interpretations	**Focus**	**Reference**
Best and modern technology to be applied in the city	Smart City focusing on technology.	[3] [4]
City with a lot of people with a lot of challenges to solved	Smart City focusing on human resources	[5] [6]
Smarter collaboration in the city	Smart City focusing on governance and managerial	[7] [8] [9]

D. Characteristic of a Smart city in Industrial City

Based on the references in this study by integrating the concept of smart city into industrial city, the categorization of smart city characteristics for industrial cities are:

- Emphasizing on support for factory production process activities
- Using the latest technology for communication between parties in the industrial process. Examples of the use of communication technology are the construction of an LTE/4G or upcoming 5G backbone line between sub-districts and connecting between government, companies, investors, and urban communities.
- Using the IoT mindset in everything. IoT allows multiple parties to share data and information.
- Realizing environmental awareness by preparing waste treatment and using energy efficiently.
- Preparing smart transportation facilities, and transportation infrastructure that allows connections between cities, ports, international airports, train stations, bus terminals are some of the facilities that must be prepared. Industrial workers need efficient transportation facilities to support their mobility.
- Implementing smart education is to help the industry to meet their needs for the workforce according to their needs. Even though technology has helped many industrial activities and has begun to reduce the role of humans, the government must also prepare a qualified workforce.

E. Pillars of Smart City

There are several things that must be prepared in order to realize smart city into industrial city. The preparation starts from citizen involvement to investment. There are several pillars of smart city development and four main development pillars [11] which is possible by the concept of IoT as shown in Fig. 1.

Fig. 1 shows that primary aspect that is required is the involvement of all parties. The government and the whole community must have the will to be involved. After that there are four main pillars: Institutional Infrastructure, Physical Infrastructure, Social Infrastructure and Economic Infrastructure. After the four pillars of development are accomplished, the next is the procurement of technology. The technology that is realized must have flexibility and sustainability. As a result, employment opportunities and quality of life for urban communities will increase. As a result, the possibility of investment will open to the city, and skills from the community will eventually be improved.

Fig. 2 below is a description of smart city composition architecture.

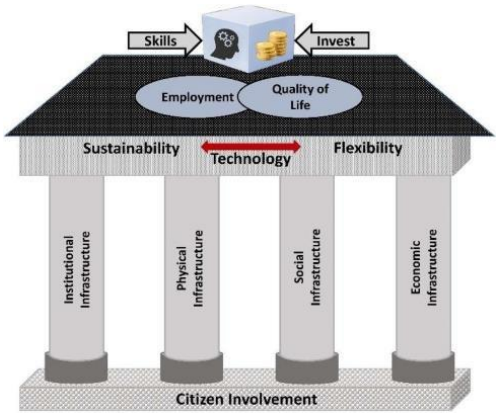

Fig. 1. Smart City's Pillars [11].

Fig. 2. Smart City Composition Architecture.

As shown in Fig. 2, smart city has supporting architectural components that can make a city become a smart city. The supporting component for the realization of smart city in a city that is prepared to become an industrial city are: smart warehouse, smart industry, smart healthcare, smart grid / energy, smart education, smart community, smart government, smart hospitality, open data, smart transportation, and smart agriculture.

III. Smart City FFR Future Industrial City

The smart city can be interpreted as using the latest technology to make other fields smart. Smart city allows connectivity between many fields in a city. Communities and governments also communicate and exchange data because of an open data concept. The following are the smart city composition architecture.

A. Smart Warehouse

In supporting industrial process, the smart warehouse becomes a necessity. The company product needs to be arranged in order to facilitate data collection and distribution process. The company also requires a qualified security system. Policy makers can see this as an opportunity. The first in first out process is arranged perfectly so that the age of the products produced is in accordance with what is predicted, and the consumer receives the new product accordingly. From the entrepreneur's side, they also need security of their products before being distributed. Technology plays an important role in the development of this smart warehouse.

B. Smart Industry

Smart industries should have concern for the environment by doing effective waste treatment and efficient use of energy sources [10][12]. We can interpret smart industry is an industry that is oriented to high quality and quantity of production by utilizing the latest technology, communication, automation, artificial intelligence, and mechatronic technology.

C. Smart Healthcare

There are several researches consider the smart health as one of smart city architectural component [10][13]. Smart health can utilize technology and process that help the citizen to get better life. The level of population growth in the city brings several challenges and obstacles to solve in the health sector. Therefore, traditional and conventional health services are no longer enough and are expected to continue to be obsolete if not improved. Physical infrastructure in the health sector must be improved, especially those using the latest technology to solve problems in handling speed, accuracy, and quantity of services. Health facilities must improve patient examination services, improve the quality of drug services, and reduce the impact of disease transmission. Currently, there are still gaps between the expectations from the government, the community, and in reality. Information technology has a great opportunity to help solve these health challenges [11].

D. Smart Grid/Energy

Energy management is one of main concern for the government. Saving and providing energy for future generations is a challenge. The energy-saving culture must be continually promoted. Then comes the concept of intelligent energy that comes with technological innovations to help make energy savings and use of renewable energy. More holistic approaches must be utilized to focus on renewable, sustainable and green energy [11]. The saving of non-renewable resources for utilization in high priority matters is the main objective of smart energy [9]. The government with smart city governance should care about the environment.

E. Smart Education

To fulfill human resources in industrial cities, an education system can be developed that produces graduates who are in accordance with the needs of the industry. If local education in the city produces graduates who have enough qualifications, it will suppress the arrival of new residents from outside the city. Improving the quality of education by utilizing technology is considered to be the answer [14].

F. Smart Community

Smart community is aimed to give more satisfaction to the citizen in the city. Giving effective and efficient government services in using technology is the goal of community satisfaction. Community needs that have been fulfilled will have an impact on the quality of life and public trust in the ruling government [11]. This section will connect several sectors of community needs in waste management, smart building governance, intelligent water management, etc.

G. Smart Government

The concept of smart government is the use of technology to assist the government in managing administration and serving the community. With Smart government, the government is fundamentally transformed into a time-efficient organization, high in performance results, and opened from the information side. Government policies become something more valuable and accountable. Community and company licensing processes are easier, cheaper and timely manner [15].

H. Smart Hospitality

One of the targets of the government is to make the city an attractive investment area. The government must welcome anyone visiting the area who may become the prospectus investors. Investors will be very happy if they get a prompt response when it comes to investment destinations. The smart city concept will handle the creation of this smart hospitality service easily [1][16].

I. Open Data

In a smart city, data is something that is the object that is sought by its citizens. Openness is needed so that the whole community can access information according to their respective privileges. For example, the community needs population data to be used as a condition for managing education, marriage, and even taking care of health insurance or insurance. Another example the government can announce the opening of an auction or the announcement of a government project auction. The government should open data as much as possible as long as it is permitted by regulation [17].

J. Smart Transportation

The government must prepare effective public transportation facilities to facilitate the high mobility of its citizen. Effective transportation can be described as a means of transportation that guarantees the mobility of citizens in a timely manner, information on transportation facilities that are easily available, safe, and there are various types of transportation to choose from. The government must prepare transportation facilities that are in accordance with the area [13][14][18]. Presenting inter-district bus transportation or working with industry to present buses as a means of transportation for employees to leave and return to work at the factory. The government can provide a means of transportation that allows for in and out access between cities and even between countries, for example:

- Light Rail Transit that connects trains with the surrounding city / district as a buffer for the city.
- International Airports that can be the gateway for people going and coming in the city.
- International Port that can be a means of supporting in and out of export and import of manufactured products as well as raw materials.

K. Smart Agriculture

In supporting a city as an industrial city, agriculture can be used as a support for the basic needs of the factory, and the food needs of the community. Increasing agricultural yields is a necessity when industry becomes a label for a city. This is because the population will automatically increase and need more food sources. Then if from the world of industry, the industrial staples should be sustained by the region itself because it will reduce transportation costs [19]. In its implementation we can use the Industry 4.0 scheme. This concept is possible to be applied to an industrial city designed as a smart city. As the first step is to build networks, second is research on two major themes related to industrial technology, and finally is to realize the integration. Smart factory and intelligent production are the big theme. The integrations are: horizontal , vertical, and end–to-end [2].

L. Priority Steps to Enable

By observing the current conditions, the Kulonprogo District government as one of the districts that want to become an industrial city should prepare many aspects. There are 4 recommended priority steps to enable smart city in future industrial city for Kulonprogo District as shown in Fig. 3.

- First step is increased shared awareness between the government and the community. The government with its political steps can create legal rules as a rule for implementing smart city. The public must be aware that technology plays an important role in improving the quality of life.
- Second step is to prepare the four pillars needed for smart cities [7][11] as shown in Fig. 1. The four pillars of the infrastructure must be prepared to become a solid foundation for the future development.
- The third step is mapping the appropriate technology needs for the city. The aim of this step is to avoid the procurement of inappropriate technology.
- The fourth step is investment. This investment in smart city can be interpreted as two types of investment: investments from the government as an organizer, and private sector investment. Investment from the government is a must. Investment from the private sector becomes support so that the project gets significantly improved. For example, when the government will build a LTE/4G or 5G communication network, the government can use the private sector to help build this communication facility [20][21]. Then the next example is calling on investors from waste treatment companies to manage municipal and industrial waste so that cities become environmentally friendly cities.

Fig. 3. Smart City Priority Steps for Kulonprogo District.

IV. Conclusion

In this paper, the view of the concept of smart cities to be applied in the industrial city initiative is proposed. Even though both have some differences, they can support each other in the development of an area that is used as an industrial city. This paper provides information about what the smart city architecture is for industrial cities, and what steps to take. A look at Industry 4.0 factories as smart city building blocks is proposed, among other architectural components such as smart health care, smart community, smart education and many more. Both concepts are based mainly on the Internet of Things and Internet which allows saving energy connecting and empowering humans.

Industry has always been an important part of the overall concept of the city and cannot be seen separately. Linking individual components can be expected through IoT. There are 10 parts to this concept: Smart Warehouse, Smart Industry, Smart Healthcare, Smart Grid/Energy, Smart Educations, Smart Community, Smart Government, Smart Hospitality, Open Data, Smart Transportations, and Smart Agriculture. The Kulonprogo District has had big dreams for the future of a city to become smart industrial city in which open data and smart governance have been initialized. This research can be continued with the application of the concepts.

It is necessary to do a research on whether the smart city development scheme for industrial city is appropriate or requires improvement. This work can be considered as a preliminary contribution to the development of empirical research in order to obtain a better understanding this smart city concept for industrial city.

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A Tool for C++ Header Generation

An Extension of the C++ Programming Language

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***Abstract*—This paper presents a novel approach in the field of C++ development for increasing performance by reducing cognitive overhead and complexity, which results in lower costs. C++ code is split into header and cpp files. This split induces code redundancy. In addition, there are (commonly used) features for classes in C++ that are not supported by recent compilers. The developer must maintain two different files for one single content and implements unsupported features by hand. This leads to the unnecessary cognitive overhead and complex sources. The result is low development performance and high development cost. Our approach utilizes an enhanced syntax inside cpp files. It allows header file generation and therefore obsoletes the need to maintain a header file. It also enables the generation of features/methods for classes. It aims to decrease cognitive overhead and complexity, so developers can focus on more sophisticated tasks. This will lead to increased performance and lower costs.**

***Keywords*—Development; C++; header file generation; feature generation**

I. Introduction

C++ is a rather old programming language with a low convenience level. Nevertheless, it is still used in schools and the industry. Updates of the C++ standard denote, the language is not dead. Further, Microsoft promotes the use of C++ through the regular renewal of its C++ IDE *Microsoft Visual Studio* [1]. Over time, advanced IDEs and updates of the C++ standard provided a better developing experience in C++. However, development with C++ is still complex and costly. One reason for that might be the split of declaration and definition into two files: header and cpp file. This induces a code redundancy that must be kept in sync. This induces a cognitive and maintenance overhead; e.g., the change of a method name must be done inside the header file *and* the cpp file. After changing one, it is necessary to remember (cognitive overhead) to also change the other (maintenance overhead). If either one is forgotten, the compiler returns an error and the code needs to be recompiled after correcting. This decreases performance and increases development cost. The question arises whether the split in two files is necessary. Comparison to other programming languages (e.g. D [2]) reveals that this split does not seem vital.

Furthermore, there are (commonly used) features for classes that are not supported by recent compilers. E.g. generation of get/set methods (implemented in C#[3]) or the ability to initialize a member variable at declaration time (implemented in Java[4]). Henceforth called *coding inconveniences*. The developer has to work around these missing features. This increases cognitive overhead and code complexity, which leads to lower performance. This leads to higher development cost.

This paper presents the idea of a text-based inline code generator, that utilizes an enhanced C++ syntax inside cpp files to generate header files and features that are not yet supported by compilers. It aims to decrease cognitive overhead for development and reduce code complexity, which leads to higher performance and lower development cost. Further, this paper introduces the tool *cppHeaderGen* which implements the presented idea.

II. Goals and Constraints as well as Related Research

A. Goals and Constraints

The overall goal is to develop a tool to improve developing experience for C++ through lowering cognitive overhead for development and complexity of source files. To achieve that the following concrete goals should be fulfilled.

1) Obsolete the need to maintain header files; header files are being generated.
2) Improve coding inconveniences; e.g. variable definition and initialization can be done in the same place.

These concrete goals should be realized while living up to the following constraints:

1) Environment independence: The tool is on the same availability level as C++ compilers. As long as C++ compilers run on a machine, it is possible to utilize the tool. This implies the following sub constraints:

a) Independence of IDE
b) Independence of build chain
c) (Source code) Independence of operating system

2) Gradual integration into existing projects possible: The tool does not enforce its project-wide usage. It can be used for specific files only. This enables a gradual integration process for existing projects.

3) Integrable into microsoft visual studio: From the authors view, Microsoft Visual Studio is an important IDE for C++ development under Windows. Therefore, the possibility to integrate the tool into Microsoft Visual Studio is mandatory.

4) Short working distance: Code changes are done *in place*. It is not necessary to open a different software or file to change currently viewed code. Otherwise slight changes, such as a variable name change, might be refrained from, because it's perceived as "too much effort for a slight change".

5) Debugging and coding in the same file: It is possible to debug and code in the same file. This reduces working distance (constraint 4)) and cognitive overhead for working with multiple files. It eliminates a possible corruption of breakpoint settings after a line number change within the code file. This is important for debugging, where *step execution and code updating* are repeated several times.

B. Related Research

There are already tools available, that aim to improve development experience for C++. The following sections introduce some of the currently available tools and illustrate their major drawback(s). The sections illustrate that currently available tools do not implement all aforementioned goals while living up to all constraints stated in Section II.A.

1) IDEs: Some IDEs (e.g. Microsoft Visual Studio [5], Eclipse [6], JetBrains CLion [7], etc.) offer great support for a better development experience in C++. E.g. classes or methods can be conveniently created or changed via the GUI. Their major drawback is their dependency on themselves and the operating system (violation of constraint 1)). Changing the IDE disables their features. Changing the operating system might enforce an IDE change.

2) Plug-Ins for IDEs: Some plug-ins for IDEs (e.g. JetBrains ReSharper [8] for Microsoft Visual Studio [5]) offer great enhanced functionality for a better development experience in C++, such as method generation. Their major drawback is their dependency on the IDE and operating system (violation of constraint 1)). Changing the IDE disables their features. Changing the operating system might enforce an IDE change.

3) Graphical code generators: Graphical code generators offer a great functionality for generating cpp and header files. They make it possible for a single change to be effective in both files. Their major drawback is the long working distance between coding and generation (violation of constraint 4)). E.g. changing the name of a member variable requires the overhead of opening the code generator software, navigating to the corresponding class and searching for the member variable declaration. This overhead might be perceived as "too much effort for a slight change". As a result, such minor changes (that might improve readability) might not be done and less readable code remains.

4) Domain specific language to C++ (text-based code generation): There is a methodology that focuses on translating a domain specific language [9][10][11] (henceforth *DSL*) to C++. This can be regarded as text-based code generation. Code generator instructions and source code are merged to one entity. Therefore, this methodology is not subject to the *working distance* drawback of graphical code generators. Its major drawback is the inability to debug and code in the same file (violation of constraint 5)). This leads to the following subsequent problems:

- During a debugging session *step execution and code updating* might be repeated several times. The DSL makes it necessary to update and debug in two different files: the DSL source file for updating code and the cpp file for debugging code. This induces a maintenance and cognitive overhead on the developer.
- While breakpoints for debugging are set inside the cpp file, coding is done inside the DSL source file. If a code change results in a line number change, the breakpoint settings inside the IDE might become obsolete. It might be necessary to re-set all breakpoints by hand.

5) Lzz–the lazy C++ programmer's tool: Lzz[12] is a text-based code generator focused on making C++ development more convenient. It can be regarded as a DSL within the ease-of-use domain. The focus of Lzz is making C++ development more convenient. Its major drawback is the inability to debug and code in the same file (violation of constraint 5)).

III. Proposed Method

To fulfill all goals and constraints from Section II.A, this paper proposes the use of a *text-based inline code generator* that utilizes an enhanced C++ syntax to generate a header file from a cpp file. It also introduces the tool *cppHeaderGen* (short for *C++ Header Generator*) as an implementation of the proposal.

A. Text-Based Inline Code Generator

The text-based inline code generator (henceforth abbreviated as *code generator*) receives a cpp file with an enhanced C++ syntax as input (see TABLE. Ifor an example list of new keywords). It generates the corresponding header file with all necessary declarations as output. Therefore, it obsoletes the maintenance of the header file (goal 1)). It can also generate (commonly used) methods such as get/set methods and provide convenient features like initialization and declaration at the same time. This improves coding convenience (goal 2)). Through the respective keywords within the cpp file the code generator knows which declarations, methods or features it needs to be generated.

B. Method Generation

Regarding method generation there are two possible solutions. As either one has its benefits or drawbacks both should be provided.

1) Generate code in a separate cpp file and add it to the list of files to compile within a project. This solution has the drawback of adding a new file to the project, which will make its structure more complex. The advantage is, that content of generated methods is not exposed to the public.

2) Generate code inside the header file and enable it only within the controlling cpp file. This solution has the drawback of revealing class internal details to the interface. The advantage is, that the number of project files does not increase.

If methods are defined within header files, it's necessary to prevent *multiple definition* errors. The mechanism to generate code inside header files without raising *multiple definition* errors is demonstrated in Fig. 1.

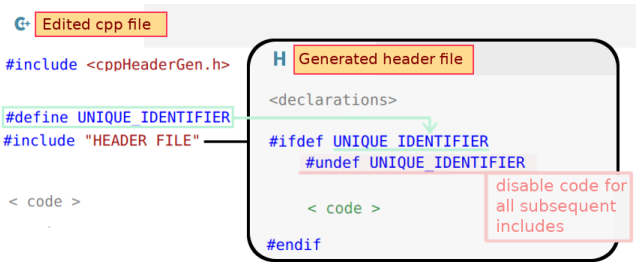

Fig. 1. Mechanism to Generate Code Inside the Header File without Raising Multiple Definition Errors.

C. Complying with Constraints

A text-based inline code generator would be the first entity within the build chain and therefore independent of any other entity (e.g. IDE) (constraint (1.1), (1.2)). To ensure independence of the operating system (constraint (1.3)), the implementation must be open source. As it is used *per cpp file*, it does not persist on project wide usage and is therefore gradually integrable into existing projects (constraint 2)). Providing a command line interface will ensure the possibility to integrate it into Microsoft Visual Studio (constraint 3)). As generated code is controlled directly via the cpp file, it remedies the working distance drawback of graphical code generators (constraint 4)) and allows coding and debugging in the same file (constraint 5)). As the content of generated methods is trivial, it's not rated a violation of constraint 5).

D. Implement Enhanced C++ Syntax

The enhanced syntax must only be visible by the code generator. It must not be visible to C++ compiler. If it would be visible to a C++ compiler, it would return compile errors. The syntax can be implemented utilizing the preprocessor. `define`s and macro definitions within a separate header file (henceforth *syntax header file*) can remove all enhanced syntax prior to compiling. To comply with constraint (1.2) it's must be ensured, that preprocessor commands are backwards compatible.

Content of the syntax header file must be contained in every cpp file that uses the enhanced syntax. This could be accomplished via a direct `include` within the cpp file or a generated `#include <cppHeaderGen.h>` inside the generated header file.

E. Limitations

1) Use of macros is inevitable: Content that is not supposed to be inside a cpp file must be removed by the preprocessor. This constraint makes the use of macros for these cases inevitable. Macros are the only possibility to remove arbitrary content through the preprocessor. Therefore, syntax as shown in Fig. 2 is not possible. Instead, syntax like in Fig. 3 needs to be used.

```
class MyClass  // class declaration start
int foo = 5;   // member variable declaration
```

Fig. 2. Impossible Syntax within the cpp File.

```
Class (MyClass)      // class declaration start
Var (int foo = 5);   // member variable declaration
```

Fig. 3. Use of Macros for Content that is not Supposed to be Inside a cpp File.

```
void MyClass::foo() { … }
```

Fig. 4. Method Definition: Method `Foo` of Class `MyClass`.

```
void foo() { … }
```

Fig. 5. Desirable Method Definition: Method `Foo` of class `MyClass`.

2) Class name before method name at definition: When defining methods in C++, it's necessary to write the class name in front of method names (see Fig. 4). However, a more convenient way as in Fig. 5 might be desirable.

Technically it is possible to remove the burden of writing the class name before the method name. However, it is suggested not to implement such a solution, because it would render currently available C++ code outliners useless.

F. Further Details

Further details about the proposed code generator are implementation dependent and are therefore described along with its example implementation *cppHeaderGen*.

IV. Example Implementation: cppHeaderGen

This chapter presents the features and implementation details of cppHeaderGen.

A. Outline

cppHeaderGen is the example implementation of the proposed text-based inline code generator for C++. It uses the cpp file with an enhanced C++ syntax as input. It basically outputs a header file containing necessary declarations. Method generation can be outputted within a separated cpp file or directly within the header file. An example input is shown in Fig. 6 and the respective output in Fig. 7.

In Fig. 6, cppHeaderGen utilizes the keywords `Class`, `ClassEnd` and `Public` to determine how the header should look like. `cppHeaderGen.h` contains code to implement these keywords. Its inclusion is mandatory to prevent compile errors (for details see Section IV.B.1)).

B. Development Environment

cppHeaderGen is written in C++ using generated files from flex (lexer)[13], GNU Bison[14] and cppHeaderGen itself.

```
#include <cppHeaderGen.h>
#include <iostream>
Class (MyClass)
  Public void MyClass::foo(int param1) {
    std::cout << "hello world";
  }
ClassEnd
```

Fig. 6. Code Example for a Class with a Method Written for cppHeaderGen.

```
//File Generated by cppHeaderGen
#ifndef _test_H_DOUBLE_INC_PREVENTION
#define _test_H_DOUBLE_INC_PREVENTION
class MyClass
{
        public:  void foo(int param1);
};
#endif
```

Fig. 7. Example Output: Code Generated from Fig. 6.

1) Implement enhanced C++ syntax: The enhanced syntax is implemented within `cppHeaderGen.h` using `define` directives and macro definitions. The content of `cppHeaderGen.h` is show in Fig. 8.

To prevent compilation errors, the inclusion of `cppHeaderGen.h` is mandatory. It's possible to generate an `#include "cppHeaderGen.h"` inside the header file using command line options.

2) New features and method generation: For features like member initialization at declaration time or method generation, there are two options as destination location for the code.

- Inside a dedicated `gen.cpp` file (default)
- Inside the generated header file

The examples in the chapters below use the `Var` keyword to trigger the generation of a standard constructor for initialization (see 5) for more details)

a) Generate methods inside a dedicated gen.cpp file (default): Generating methods inside a dedicated gen.cpp file is the default setting. It's necessary to add the generated file to the *list of files to compile* (e.g. the project). Fig. 9 shows an example input for generating a constructor for a class. Fig. 10 shows the generated output.

```
#ifndef CPPHEADERGEN_H
#define CPPHEADERGEN_H

#define Class(…)
#define ClassEnd

#define HF( ... )
#define Include( ... )

#define Def
#define GlobalVar
#define ExternVar

#define Static
#define Virtual

#define Public
#define Private
#define Protected

#define PublicVar( ... )
#define PrivateVar( ... )
#define ProtectedVar( ... )

#define Var( ... )

#define GENERATE_copyNonPointerMember

#define CTOR __init

#endif
```

Fig. 8. Content of `cppHeaderGen.h`.

```
#include <cppHeaderGen.h>
#include "myclass.h"
Class ( MyClass )
  Var(public; int; foo; 8); // define a new variable
ClassEnd
```

Fig. 9. Example Input: Class with a Member Variable Definition. Setting a Default Value ("8") Triggers the Creation of a Standard Constructor.

```
#include "myclass.h"
MyClass::MyClass() : foo(8) {}
```

Fig. 10. Example Output: Content of File `Myclass.gen.cpp` from Fig. 9.

b) Generate methods inside header files: If it's desirable to generate only one file, methods can be generated directly into the header file. This might expose class-private data through the header file. To activate this option a specific `define` is set inside the cpp file before the inclusion of the corresponding header include. The `define` complies with the following pattern: `#define genInHeader_`[unique identifier]. Fig. 11 shows an example input and Fig. 12 shows the generated output.

3) Support for older compilers: The invalidation of the enhanced syntax uses macros with variable parameter count (henceforth: *variadic macros*). Some older compilers [15] do not support variadic macros. For older compilers there is a different header file to include: `cppHeaderGenNoVar.h`. Macros inside this header are not defined *variadic*. An extract of the file is shown in Fig. 13.

Using this include file changes the enhanced syntax. Instead of single brackets for macros, double brackets are used. Fig. 14 shows an example for the `Class` macro.

```
#include <cppHeaderGen.h>
#define genInHeader_MyClass
#include "myclass.h"
Class ( MyClass )
  Var(public; int; foo; 8); // define new variable
ClassEnd
```

Fig. 11. Example Input: Generate Methods Inside Header File. The Trigger for Generating Methods Inside the Header File is Marked Bold.

```
[…]
class MyClass { […] }

#ifdef genInHeader_MyClass
#undef getInHeader_MyClass
MyClass::MyClass() : foo(8) {}
#endif
[…]
```

Fig. 12. Example Output: Code Generated From Fig. 11. "[…]" is used as Abbreviation of Content.

```
#define HF( A )
#define Include( A )

#define Def
#define GlobalVar
#define ExternVar

#define Static
#define Virtual
```

Fig. 13. Extract of File `cppHeaderGenNoVar.h` that Shows a Non-Variadic Macro Definition.

```
Class(( MyClass ))
  Public void MyClass::foo(int param1) {
    std::cout << "hello world";
  }
ClassEnd
```

Fig. 14. Example Input: Double-Bracketed Enhanced Syntax for Support for Older Compilers. The Parameter List of the Method is Not Part of the Enhanced Syntax. Therefore it must not have Double Brackets.

```
Class( MyClass : public Base1, Base2 )
```

Fig. 15. Demonstration of a Macro Containing Two Parameters.

4) Variadic macros: The reason why variadic macros are necessary is because even a simple class definition with several base classes contains a comma, which is interpreted by the preprocessor as *multiple parameters* (see Fig. 15).

5) Keyword list: The following TABLE. Iintroduces all keywords and features provided by cppHeaderGen at the time being.

6) Management features: Regarding file generation cppHeaderGen provides the following features.

- No double inclusion

Double inclusion of headers is avoided through the `#ifndef` include guard directive.

- Handwritten header files do not get overwritten

Every generated header file contains a specific comment that marks the file as *generated*. A header file will only be overwritten, if it is marked as *generated*.

- Only renew on change

A header file is only renewed, if its content changed. This preserves file generation timestamps and therefore prevents unnecessary rebuilds.

7) Integration into microsoft visual studio: Integration into Microsoft Visual Studio can be accomplished through *pre-build events* within the project settings.

TABLE. I. LIST OF ALL KEYWORDS AND FEATURES PROVIDED BY THE SYNTAX OF CPPHEADERGEN (SEE 6) FOR FILE MANAGEMENT FEATURES).

Keyword	
Explanation	***Example***
HF([content]))	
Copies [content] verbatim into the header file. All hashtags within [content] must be escaped with a backslash.	Example input: HF(// copy to header file. \#ifdef FOO \#endif) Example output: // copy to header file. #ifdef FOO #endif
Include("[filename]") / Include(<[filename]>)	
Creates an include statement inside the header file.	Example input: Include(<string>) Example output: #include <string>
Class ([classname]) / Struct ([structname])	
Denotes the start of a new class. In the current version nested classes are not fully supported.	Example input: Class(MyClass) Example output: class MyClass {
ClassEnd	
Denotes the end of Class.	Example input: ClassEnd Example output: }
Public / Private / Protected	
Denotes the start of a method definition with the given visibility.	Example input: Public MyClass::foo(int param) { ... } Example output: public: foo(int param);
Static	
Keyword used to declare a method static.	Example input: Public Static void MyClass::foo() { ... } Example output: public: static void foo();
Virtual	
Keyword used to declare a method virtual.	Example input: Public Virtual void MyClass::foo() { ... } Example output: public: virtual void foo();

<table>
<tr><td colspan="2">Var([visibility]; [type] ; [variable name])</td></tr>
<tr><td>Create a member variable declaration inside the header file. This notation develops its full potential when used with GENERATE_copyNonPointerMember.</td><td>Example input:
Var(public; int; var)
Example ouput:
public: int var;</td></tr>
<tr><td colspan="2">Var([visibility]; [type]; [variable name]; [initialization value])</td></tr>
<tr><td>Create a member variable declaration inside the header file and initialize it with 7. The initialization is realized through the generation of initializer lists and constructors. If no custom constructor is defined, a standard constructor will be generated.</td><td>.Example input:
Var(public; int; var; 7)
Example ouput:
public: int var;
[...]
MyClass::MyClass() : var(7) {}</td></tr>
<tr><td colspan="2">GENERATE_copyNonPointerMember</td></tr>
<tr><td>Generate a method that copies the content of all declared non-pointer variables to another object. Only variables declared via Var() are considered.</td><td>Example input:
Class (MyClass)
Var(public; int; var)
GENERATE_copyNonPointerMember
EndClass
Example ouput:
class MyClass {
private:
void copyNonPointerMemberFrom
(const MyClass & source);
[...]
void MyClass::
copyNonPointerMemberFrom (
const MyClass &source)
{
this->var = source.var; }</td></tr>
<tr><td colspan="2">[visibility] void [classname]::CTOR([parameter]) {}</td></tr>
<tr><td>Generate a constructor for the class [classname]. It must be used in conjunction with a visibility indicator (Public / Private / Protected) and the classname.
Inside cppHeaderGen.h CTOR is changed to __init through the following define:
#define CTOR __init</td><td>Example input:
Public void MyClass::CTOR
(int param1)
{ }
Example output:
public: inline void __init
(int param1);
public: MyClass(int param1);</td></tr>
<tr><td colspan="2">Def [function definition]</td></tr>
<tr><td>Create a declaration for a (global) function. The namespace of the function will be stripped away.</td><td>Example input:
Def std::string myNamespace
::foo(int param){}
Example output:
std::string foo(int param){}</td></tr>
<tr><td colspan="2">GlobalVar</td></tr>
<tr><td>Create an extern declaration for a given variable.</td><td>Example input:
GlobalVar int gValue = 1;
Example output:
extern int gValue;</td></tr>
<tr><td colspan="2">[method generation]</td></tr>
<tr><td colspan="2">By default methods are generated inside a dedicated gen.cpp file. The generated file must be included in the list of files to compile. Methods can also be generated inside the header file.</td></tr>
<tr><td colspan="2">#define genInHeader_[unique specifier]</td></tr>
<tr><td>Instructs the generator to generate methods directly inside the header file. No seperate gen.cpp file will be generated. The define must be set before the associated header file is included.</td><td>Example input:
#define genInHeader_MyClass
#include “myclass.h”
Class (MyClass)
Var(public;int;foo;8)
EndClass
Example output:
class MyClass{
public: int foo;
public: MyClass();
}
#ifdef genInHeader_MyClass
#undef genInHeader_MyClass
MyClass::MyClass() : foo(8);
#endif</td></tr>
</table>

C. Limitations

1) Syntax for member variable declaration: The current syntax for variable declaration (`Var(` [visibility]; [type]; [name]; [initial value]`)`) is very different from the C++ standard. The reason why this syntax was chosen over a more native syntax is that it's easier to parse. In future versions the syntax shown in Fig. 16 might become supported.

```
PublicVar ( int foo = 5 )
PrivateVar( const string foo("hello") )
```

Fig. 16. Possible Future Syntax for Variable Definition.

The reason why a syntax as shown in Fig. 17 cannot be supported is that `Public` is already defined as `#define Public` (non-macro definition). Creating a macro with the same name is not allowed by the preprocessor.

```
Public( int foo = 5 )
```

Fig. 17. Possible Future Syntax for Variable Definition.

2) Class name before method name at definition: Removing the need to write a class name before a method name at definition time renders a code outliner useless. To ensure a working C++ code outlining, no measures are taken to eliminate the need to write the class name before method names at definition time.

3) CppHeaderGen can only process one file per call: It is not possible for cppHeaderGen to process multiple files or whole directories per. If such functionality is needed (e.g. as for Section III.7)), it's necessary to use an external program or script that calls cppHeaderGen multiple times.

D. Example

Fig. 18 shows an example of a generated header file. On the left side, there is the manually created file *myclass.cpp*. On the right side, there is the generated file *myclass.h*. Fig. 19 demonstrates the use of class *MyClass* defined in Fig. 18. Particularly it demonstrates the use of the generated method for copying non-pointer member variables.

myclass.cpp × Edited cpp file

```
1  #include "cppHeaderGen.h"
2
3  #define genInHeader_MyClass
4  #include "myclass.h"
5  Include( <string> )
6  Include( <iostream> )
7
8  HF( using namespace std;)
9
10 Class ( MyClass )
11   Var( private;  string; _content; "Hello World")
12   Var( private;  int;    _printCounts; 3)
13
14   Public void MyClass::setTimesPrint(int count){
15     _printCounts = count;
16   }
17
18   Public void MyClass::print(){
19     for ( int i = 0; i < _printCounts; ++i){
20       cout << _content << endl;
21     }
22   }
23   GENERATE_copyNonPointerMember
24   // copy ctor does not need initializer lists
25   Public MyClass::MyClass(const MyClass & myclass){
26     copyNonPointerMemberFrom(myclass);
27   }
28
29 ClassEnd
30
31 // ---------------------------------
32
```

myclass.h × Generated header file

```
1  //File Generated by cppHeaderGen
2  #ifndef _myclass_H_DOUBLE_INC_PREVENTION
3  #define _myclass_H_DOUBLE_INC_PREVENTION
4
5  #include  <string>
6  #include  <iostream>
7   using namespace std;
8
9  class  MyClass
10 {
11     private: string  _content;
12     private: int  _printCounts;
13     public:  void setTimesPrint(int count);
14     public:  void print();
15     private: void copyNonPointerMemberFrom( const MyClass & source);
16     public:  MyClass(const MyClass & myclass);
17     public:  MyClass();
18 };
19
20 #ifdef genInHeader_MyClass
21 #undef genInHeader_MyClass
22 void MyClass::copyNonPointerMemberFrom( const MyClass & source){
23     this->_content     = source._content;
24     this->_printCounts = source._printCounts;
25 }
26
27
28 MyClass::MyClass() : _content("Hello World"), _printCounts(3){}
29
30
31 #endif
32 #endif
```

Fig. 18. Example Generation of File Myclass.H Containing Declarations and Definitions for Class Myclass. The Input File (*Myclass.Cpp*) is Shown on the Left. The Output File (*Myclass.H*) is Shown in the Right. Colored Areas Indicate Correlated Code. The Following Features are in use: Method Generation in Header File, Include, Verbatim Copy to Header File, Variable Definition and Initialization, Constructor Generation, Method Declaration, Generation of Member Variable Copy Method.

```
int main()
{
  MyClass printer1;
  cout << "printer1:\n";
  printer1.print(); //  3x "hello world"

  printer1.setTimesPrint(5);

  cout << "printer2:\n";
  MyClass printer2(printer1);

  printer2.print(); //  5x "hello world"

  return 0;
}
```

Fig. 19. Example Program: uses Myclass from Fig. 18 to demonstrate the use of the Generated Method `CopyNonPointerMemberFrom`.

V. Discussion

Using cppHeaderGen in practice smoothened C++ development. For developing cppHeaderGen itself usage of cppHeaderGen is already part of the build chain. For small-sized projects or projects without a full-featured development environment cppHeaderGen is rated worth using by the author. There is no experience regarding the usage in large projects.

VI. Conclusion

This paper worked on a concept for improving the development experience in C++. It presented the idea to utilize a text-based inline code generator controlled by a cpp file to generate and obsolete the need to manually maintain the according header file. It could improve coding inconveniences, as it was able to provide new features to the C++ language (like initialization at declaration time) and method generation. This paper introduced the tool cppHeaderGen, which implemented the idea of a text-based inline code generator. cppHeaderGen took a cpp file with an enhanced C++ syntax as input and outputted the corresponding header file. cppHeaderGen successfully obsoleted the need to maintain the header file. It allowed for a more convenient developing experience through the ability of method generation. E.g. it allowed member variable initialization at declaration time. It was independent of the underlying operating system, IDE or build chain and could gradually be integrated into existing projects. It was integrable into Microsoft Visual Studio. All coding was done in place. Therefore, it had a short working distance and coding and debugging could be done in the same file.

VII. Future Work

The code generator runs before the compilation process and therefore allows for a wide spectrum of possibilities regarding code generation. Future work should focus on finding new helpful features and generatable methods. Research should also be done regarding *helpfulness of a paradigm change*, such as making `virtual` the default modifier for method declaration.

cppHeaderGen should implement further, already known features to evaluate their usefulness. At the time being, the following features are candidates for future implementations.

- Generation of `get` / `set` methods for member variables.
- Generation of virtual clone methods for classes.
- More native-like syntax for variable declaration, like `PublicVar(int foo = 5)`.
- Generation of enum classes.
- Constructor initialization through parameters.
- Generation of a method that deletes all pointers.

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Authors' Profile

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Heuristic Evaluation of Serious Game Application for Slow-reading Students

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***Abstract*—The findings of preliminary studies found that conventional approaches were still relevant but students showed weak and moderate interest and quickly lost focus rather than technology approaches such as serious games were used especially for slow reading students (SRS). Most teachers use interventions that are not specifically designed to help SRS. They usually use teaching aids below the literacy level of the SRS. Therefore, an easy and user-friendly games application called "Mari Membaca" or M2M was developed. The objective is to make sure the application is free from design and interface problems by demonstrating the application of expert-based usability evaluation techniques such as Heuristic evaluation. This paper reports the experimental heuristic evaluation of M2M for SRS among expert evaluators includes remedial teachers and game developers. This study adopted ten Usability Heuristics and seven brain-compatible instructional phases of brain-based learning to be included in the questionnaire. The overall result derived from the evaluation is 14 out of 17 (3.41-5.00) above average mean score, which are neutral (2.61-3.40) in one domain. Several comments and feedback from the experts were essentials for further improvement of the game application to ensure meets the user requirement and expectation.**

Keywords*—Serious game; brain-based learning; heuristic evaluation; literacy skills; slow-reading students

I. Introduction

Struggles in reading can cause difficulties in all subject areas. Mastery in reading skills can influence in the progress or failure in daily performance especially in the examination [1]–[3]. Reading is a skill that requires several abilities (comprehension, visual and auditory processing) working together to be able to master. If a child is weak in any of those abilities, it can impact the ability to read [4]. A slow-reading student (SRS) is one of the most problematic learning problems since reading is the most crucial principle in learning. A "slow learner" is not a diagnostic category; they may have ordinary lives outside of the classroom. However, academic subjects are a challenge for them. SRS is lack in understanding compare to their peers but they do has their own ability to learn academic skills [5]. They are slightly different from their peers in terms of potential which they are struggling to meet the academic demands in normal class. Cognitive abilities, levels of understanding and thinking may differ slightly from other students, but still they are categorized as normal students [6], [7] because they still able to learn the learning skills [8]. Author in [9] state as well as having low cognitive, they also have memory and weak concentration and can hardly describe their ideas. SRS has limited capabilities when it involves symbols and abstracts such as language, numbers and concepts. They need more stimuli, encouragement, time and attention as well as technology and aid tools to help them in learning. The use of games in teaching and learning (T&L) is increasingly gaining attention by teachers. The use of this medium is seen as an intervention tool to help SRS master the reading skills.

Serious games are an innovative teaching method that can enhance learning and entertainment to meet the needs of different children, especially students who are left behind in learning. Author in [10] refer the word 'serious' as the function of the game in delivering input in the form of education or training to players. Author in [11] stated that serious game was referred to as an entertainment tool with educational goals, in which the player fostered knowledge and practiced their skills while playing. In [12], a serious game designed that is interactive and has educational goals on any digital platform that created an active learning environment. In addition to the game intervention used, regular strategies are also important for achieving goals. The strategy covers aspects such as methods, techniques and approaches used.

There is a very different approach in learning to help educators today in evaluating, teaching and curriculum planning [13], which is brain-based learning (BBL) approach [14], [15]. In this serious game, the integration of the BBL approach is seen as an intervention in T&L to help students optimize the brain use and stay focused on learning. According to [16], BBL give a positive impact on student achievement because BBL focuses on brain function. The function of the brain can be fully optimized by the help of teachers and teaching aids using the liked and comfortable approach to enhance the individual self-potential. The most approach liked by students is the game [17]. The use of this BBL approach is selected as most have been applied indirectly by teachers in T&L. As a result, a serious game compatible brain-based learning has developed. The objective is to obtain feedback and usability from expert by conduct a heuristic evaluation on game application or well known as M2M. Second subtopic will discuss on related work regarding this paper. Third, briefly describe about usability evaluation and advantage using heuristic evaluation. Fourth, explain the method use on this paper. Fifth, show the results and discussion about it. Lastly, conclusion and future work that can be expand from this paper.

II. Related Work

In this section, brain-based learning (BBL) and implementation of BBL in serious game will discuss as it the main key themes in this study.

A. Brain-Based Learning (BBL)

BBL is a technique of neurological and cognitive science studies that are used to improve teacher teaching. This approach was introduced three or four decades ago through a study revolution on the brain to help educators in planning, evaluating, teaching and curriculum [13]. In order to ensure the effectiveness of individual learning, this teaching approach is designed to fit the structure, tendency and optimum function of the human brain. Unlike conventional learning, this theory approach is based on every human being can learn as long as their brains do not forbid such routine processes[14], [15].

In [16] has implemented a BBL strategy based on twelve BBL principles developed by [14] through three teaching techniques related to this principle. According to [18], BBL has three closely related elements:

1) Relaxed alertness: Eliminates doubts within the student while maintaining a challenging learning environment. In this context, the provision of a less threatening environment but a challenge is through a serious game. Students are happy and comfortable to learn while playing the activities and exercises provided.

2) Orchestrated immersion: Creating a learning environment that gives students a meaningful experience. In this context involves the integration of learning experiences based on the student's tendency (play).

3) Active processing: Allows the student to unify and understand the information received [14]. In this context, active processing leads to serious game training and activities that encourage students to connect and deepen active knowledge.

BBL also affects students' academic achievement. Authors in [19], [20] stated that BBL can accelerate the process of thinking, planning and implementation processes that enhance the concept of understanding and motivation in learning. In Malaysia there are several studies using the BBL approach. Among them are [19] stated that the use of BBL method in learning can enhance the students' knowledge in the electric concept. Based on the study conducted by [21], brain-based teaching has improved the understanding of the students about the concept of Newton's Physics than traditional methods. Improve student understanding of concept and mechanism of photosynthesis [18]. The BBL method emphasizes active learning that can stimulate the brain which can help thinking skills, reduce stress and improve learning. Integration of BBL strategy in a serious game is expected to help improve SRS literacy skills while maintaining student motivation to continue learning.

B. Implementation of Brain-Based Learning in Serious Game

The basic difference between learning goals and game goals is learning goals are the intellectual knowledge and skills we want students to learn in the game, while the goal of the game is when players can complete all activities in the game [22]. So, when designing a serious game, designers need to consider how learning goals can interact with the goals of the game and how other approaches support this goal. Intervention of BBL approach in games is seen to be able to help slow-reading students (SRS) improve their understanding and motivation in T&L. In this study, students are need to complete three situations which are i) fun learning (serious games), ii) learning using their syllabus and in relation to prior knowledge iii) actively involved in all seven phases of brain-compatible teaching by [23]. The seven phases of the teaching are:

1) Activation: Serious game content developed should be able to activate the memory and early learning of the students by involving their syllabus to stimulate the transmission of information.

2) Clarify the outcomes that need to be achieved and the learning process involved: The objective of the game's learning is shown before the player starts a game session. This is to give an overview of the ideas taught and enable students to reinforce the learning target and activate the right brain and the left brain and eliminate anxiety in the student.

3) Making connection: Activities linking prior knowledge are an important in this approach. This process stimulates the brain to make connections based on student understanding to integrate new information with the existing one.

4) Carry out learning activities: This activity requires a thorough involvement by each student in every activity and allows students to digest, think, reflect, and look for the logical experience gained in visual, audio and kinesthetic in the game.

5) Demonstrating student's understanding: Students can test their understanding of involving the review process and repeating the newly acquired knowledge or skills and encouraging the transfer of information to the student's long-term memory system.

6) Review for students' retention: Activity in this game is an assessment to test and assess their understanding and acceptance of new concepts.

7) Preview next topic: The main menu featuring the topics learned provides the brain to prepare and help the brain to focus on learning in the next learning session.

According [18] stated that interactions between BBL principles elements were relax alertness, Orchestrated Immersion and active processing with brain-compatible teaching phases were seen to stimulate the learning motivation to create more effective learning. In [16], students' exposure to brain-based teaching strategies has helped students to focus more on learning and ability to achieve the highest level of learning. Teaching strategies that involve auditory, visual and kinesthetic provide space for students to maximize their learning abilities to improve learning outcomes.

III. Usability Evaluation

The successful interactive software application depends on usability which is an important factor for all software quality models. A technique that is frequently used in the field of Human-computer Interaction is usability evaluation. To ensure game acceptance and positive reviews from players, game usability should be emphasized. Usability is important in game development as well, as it optimizes player engagement

and accomplishment of individual and organizational objectives [24]. Some of the best-known usability models are those of the International Organization for Standardization [25]. This ISO are produced by international groups of experts after a careful review process. The definition of usability essentially consists of: 1) Effectiveness. 2) Efficiency, 3) Satisfaction.

Author in [26] state that using this evaluation it can help researcher to find a problems and provide suggestions to improve the system. A good user interface design typically needs the use of a variety of usability evaluation methods [27], [28]. Heuristic evaluation is an inspection method that appears frequently in the literature and experts preferred used it to determine usability problem in any application or product [29], [30].

Based on this study, researcher had chosen heuristic evaluation. Heuristic assessment is a software usability assessment tool that is widely used in the industry because it does not require much infrastructure, time and cost [32]–[34].

A. Heuristic Evaluation

Heuristic assessment is a usability inspection technique developed by [31], [35]. According [36], most of the research which is 60% of cases used Nielsen as the benchmark. According to [37], heuristic evaluation (HE) techniques previously used in software evaluation (systems and products) have now appeared in popular applications of games. Heuristic assessments are carried out by expert evaluation groups rather than actual users. Potential usability problems are grouped in a usability report. According to [38], most heuristic assessments are informal but their advantages are fast because assessed by experts, do not require high cost and efficient [38]–[43] and are suitable for use in every phase of the software cycle phase even after system execution [40]. HE does not need a fully functional prototype.

In the context of this study, teachers and game developers become evaluator in the assessment process. This is because the teacher's expertise in assessing the appropriate game content and the developer's expertise in evaluating the appropriate game elements. They examined a user interface and judge for compliance with recognized usability principles called “heuristics”. The Heuristic Evaluation process can be separated in three major phases: An inspection phase, in which evaluators independently evaluate the user interface; a preparation phase where evaluators independently prepare their list of identified problems for aggregation; and an aggregation phase, in which evaluators together collaborate to generate a single report of usability problems. The lists of potential usability problems then are analyzed by researcher to agree and work on the usability problem fixes and priorities. Fig. 1 depicts the overall Heuristic Evaluation process.

IV. Method

This study used heuristic evaluation to determine which problems in the interface of M2M tool that not suit to SRS. The result is used to enhance design better than before. Selected specialists were participating in the evaluation to identify the usability problems.

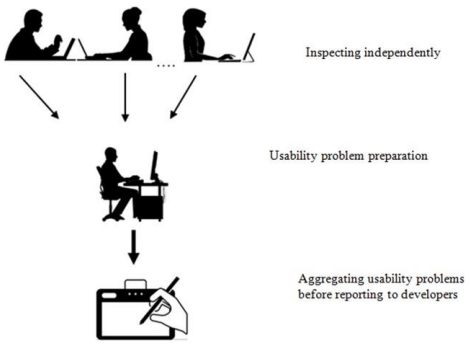

Fig. 1. Heuristic Evaluation Overview.

A. Sample of Study

For the total number of evaluators, usually 5 [44], [45] up to 8 assessors [46] are used in heuristic assessments. Seven specialists were involved that were selected based on the qualification and experience related to slow-reading students (SRS) and development of games. Table I shows the profile of expert evaluators.

B. Research Instrument

The instruments use to conduct this study include:

1) Questionnaire: Heuristic evaluation was used as a basis in the questionnaire for the evaluation of M2M. To perform a heuristic evaluation, it is necessary to adopt a list of principles to Heuristic evaluation was used as a basis in the questionnaire for the evaluation of M2M. To perform a heuristic evaluation, it is necessary to adopt a list of principles to guide the inspection. To evaluate the interface design, the following is the set of usability principles (Nielsen, 1994), which was used in this research. The questionnaire made up of three (3) sections: (A) Demographic, (B) Usability Heuristic for User Interface Design - which used the traditional Nielsen’s heuristics and (C) BBL Heuristic - which embrace the twelve BBL principles developed by [14], through three teaching related to this principle that are considered techniques related to this principle that are considered essential for effective learning. The heuristic for game application is showed in Appendix A and B.

TABLE I. Profile of Evaluator

Evaluator	Professional Role	User Experience (Years)	
		Slow-reading Students	Games
1	Teacher	6	-
2	Teacher	9	-
3	Teacher	12	-
4	Teacher	7	-
5	Teacher	5	-
6	Game developer	-	3
7	Game developer	-	5

2) Hardware and software: Hardware used for the development of this tool was notebook and mouse. While, software used is Unity as a main authoring tool, Adobe Photoshop CS4 for graphic editing and Audacity for audio recording and editing.

3) Game application (M2M application): M2M is a computer based and stand-alone application. It consists of five modules; "Huruf", "Suku Kata Terbuka", "Perkataan", "Ayat Mudah" dan "Cerita & Lagu". Fig. 2 to 6 shows the main screenshots of the apps.

Fig. 2 shows a screenshot for main menu that displays each module available in this application. The user can click on any module to begin the application but for the first time user, teacher will guide to start with first module which is "Huruf" and so on. First module, users are required to completed two activities: i) Connecting the dot letters 'a' to 'z', and ii) Listening to phonic audio for the letters.

Fig. 3 shows a screenshot for the "Suku Kata Terbuka" menu. For each module chosen by the user, they will be shown with learning objectives before starting the game to give the user an overview of the game objective. Two activities involved; "Tarik & Letak" and "Pusing & Padan".

Fig. 4 shows a screenshot for the "Suku Kata Terbuka" menu. In this first activity "Tarik & Letak", user needs to choose the correct syllable to form a word from options provided by drag on it and drop into box. Picture is provided to give an idea to user.

Fig. 2. Main Menu of M2M Game Application.

Fig. 3. The Objectives will be Preview on the Front of the Module.

Fig. 4. Menu of "Suku Kata Terbuka".

Fig. 5 shows a screenshot for the "Frasa Perkataan" menu. In this activity, user needs to choose the correct words based on the picture given. User must select the answer from options provided by drag on it and drop into box. Picture is provided to give an idea to user.

Fig. 6 shows a screenshot for the "Ayat Mudah" menu. In this activity, user needs to choose the correct words based on the picture given. User must select the answer from options provided by drag on it and drop into box. Picture is provided to give an idea to user.

C. Evaluation Process

Heuristic evaluation of M2M application was conducted through offline activities where the apps were installed in the researcher laptop. The procedure of the evaluation consists of following steps as follows:

Fig. 5. Menu of "Frasa Perkataan".

Fig. 6. Menu of "Ayat Mudah".

1) Offline invitation: For teacher, researcher applied for permission from the Ministry of Education (MOE) to conduct the study. After the MOE issued a letter, the researcher requested the permission from the Labuan Federal Territory Education Department and then applied for the permission of the school. Researcher set a date with the experts for the evaluation and on that day the explanation of the evaluation purposes was given. For game developer, researcher set a date with the experts via call and on that day the explanation of the evaluation purposes was given.

2) Demonstration of the application: The researcher demonstrates the operational of application and after that the experts can use the apps. Next, the questionnaire was given to the experts.

3) Feedback: The specialist evaluated the application based on the provided questionnaire. Each participants answered a total of 17 questions based on a 5-Likert Scale (1 – strongly Disagree, 2 – Disagree, 3 – Neutral, 4 – Agree, 5 – Strongly Agree). Then, the questionnaire was collected. The specialist gave suggestions to deal the problems and also comments in order to improve the apps. Once the evaluation process completed, the data were analyzed accordingly.

V. Result and Discussion

A. Heuristic Evaluation Result

Fig. 7 shows the mean score of the result from questionnaire analysis. Overall, the result indicate that the respondents agree and neutral on the heuristics criteria.

The results showed that, according to the respondents, the apps got acceptable rating in most aspect covered by game heuristic. For game heuristic, "INT 5: Error prevention" has 4.86 mean score which is the highest rating. Second highest is "INT 8: Aesthetic and minimalist design" by 4.57. Third highest are "INT 4: Consistently and standards" and "INT 9: Help users recognition, diagnose and recover from errors" which are 4.43 and followed by "Q1: Visibility of system status" and "Q2: Match between system and real world" obtained a score 4.29. The "INT 6: Recognition rather than recall" had mean score 3.86 individually. These heuristics have mean score more than 3.41, which means that users were between agree and strongly agree with these six usability heuristic of the apps.

The "Q3: User control and freedom" obtained a neutral score which is 3.00. User are able to undo mistakes by given two chances but user not able to exit locations and if customer want to exit they need to exit apps. Meanwhile, heuristic "INT 7: Flexibility and efficiency of use" obtained a mean score 2.14 and "INT 10: Help and documentation" obtained a mean score 1.57 which is the lowest score and users were strongly disagree with these two heuristics off the apps. This app does not allow experienced users to use shortcuts and adjust setting yet as this low-fidelity prototype not complete yet. This prototype also doesn't provides appropriate online help as this apps is offline mode and documentation to make user easily accesses are not provide as this apps is for SRS which is they are weak in literacy. They will be guide by teacher.

For BBL heuristic, the results showed that, according to the respondents, the application got acceptable and had a particularly good rating in all aspect.

For game heuristic, "INT 2: Clarify the outcomes that need to be achieved and the learning process involved" has 4.86 mean score which is the highest rating. Second highest of the mean score is "INT 1: Activation" by 4.43. Third highest of the mean score is "INT 7: Preview the next topic" by 4.23. Meanwhile, heuristic for "IN4: Carry out learning activities" and "INT 5: Demonstrating student's understanding" had mean score 4.00 individually. Both the "INT 3: Making connection" and "INT 6: Review for students' retention" had mean score 3.71. These heuristics have mean score more than 3.41, which means that users were between agree and strongly agree with these six approaches of BBL heuristic of the apps.

Overall, the findings from the questionnaire were positive even though some of game heuristic received neutral score and two had negative from the experts. While the approach that applied seven phase compatible brain receive all positive feedback. Obviously, certain aspects of the M2M apps need to be improve based on the score of usability heuristic to ensure the apps is ready to be commercialized soon.

B. Feedback and Comments from Expert

Apart from the observations from the analysed data, the participants also give the feedback and commented on some advantages and weaknesses noticed in the games. The feedback and comments are as follows in Table II:

The comments of the teacher users focused more on the content that will make sure it suits the SRS level. While the comments from game developers are to improve the graphic user interface of the system for enhancement of features that will make the system complete.

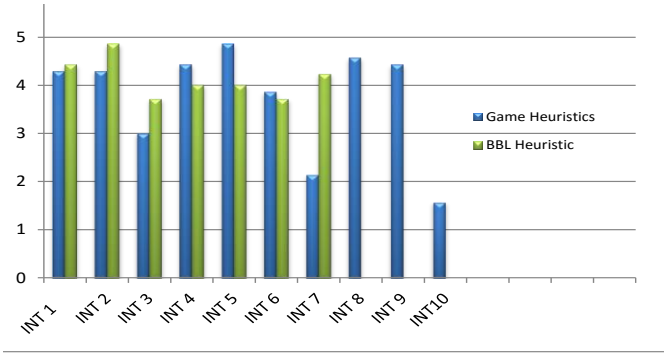

Fig. 7. Mean Score of the Questionnaire Analysis.

TABLE II. FEEDBACK AND COMMENTS

No.	Feedback/ Comments	Action to be Taken
1.	The aesthetics of the games application in terms of colour blend and appearance are attractive as using a bright color.	Using bright and contras color to attract SRS attention.
2.	In activity "Tarik & Letak" in module "Suku Kata Terbuka" the number of the questions is suitable for SRS level and animation need to be reduce because it may disrupt SRS attention.	It follows BBL strategy that for one activity the max time to be completed by SRS is around 9-12 min. Animation for this module will be deleted.
3.	For font in this app, Times New Roman is not suitable for SRS. Experts (Teacher) give a list of font name that suitable for SRS.	The font list that will use is Waknan font.
4.	The game apps need to be more user-friendly. User is able to exit the game without going back to main menu.	Add exit button in game setting.
5.	The experts suggest that the proper time to implement the game for SRS is at the first quarter of year.	Researcher will start the testing on April 2019 as per suggest.
6.	It should be possible to access help in a very easy way.	Hint will be given after two tries.
7.	This apps is new approach to help SRS in literacy using computer based application and use multimedia elements (audio, graphic), and BBL approaches which is very attractive and suitable to SRS.	Combine the entire multimedia element together with BBL strategies.
8.	The games is easy to learn and suitable for SRS that have mild problem in literacy.	Follows the Pemulihan syllabus as guideline.

VI. CONCLUSION AND FUTURE WORK

In this study, M2M was developed for slow reading student as one of the teaching aid material to help teacher at school. It uses Malay Language as a main language in order to ensure the questions are well understood. It consists of five modules. This study was conducted to determine its usability via heuristic evaluation. A set of 17 customized heuristics that belongs to game heuristics and BBL heuristics were used to evaluate the games application. The evaluation result revealed that most of the questionnaire domains score as average and above average and earned good rating in many aspects assessed. Two questionnaire domains in game heuristics were rated low by users. This implies that the design of the games should be improved to ensure that it maximally supports students' learning. Meanwhile, the evaluation result revealed that all of the questionnaire domains in BBL heuristic score above average in all aspects assessed. This implies that BBL approaches are acceptable and can help to fully optimize SRS brain to enhance SRS literacy skills. The result of the heuristic evaluation also revealed the strengths and weaknesses of the games apps.

Besides, the evaluators also provide a positive feedbacks and comments. Those evaluation and feedback from the experts are essentials to further improve the application in order to meets the user requirement and expectation. The comments of the teacher users focused more on the content and enhancement of features that will suit SRS. Meanwhile, the comments from developer user focused more on the enhancement of features that will make the system complete.

There may be some possible limitations in this study. This study is focused on SRS but this evaluation not involved them as it is difficult for the SRS to understand the questions. The teachers involved also only for LINUS and Pemulihan teachers as they know the needs and requirements of SRS. SRS can only be involved with qualitative data collection because of their lack of understanding in written instructions if quantitative studies are carried out.

In future work, the improvements of M2M apps will be carried out and usability testing conducted in order to get real and reliable result. Once its' validity and reliability is tested in real population, M2M can be used commercially to SRS.

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APPENDIX A

1. Visibility of system status
- Does the application include a visible title page, section or site? - Does the user always know where it is located? - Does the user always know what the application is doing?
2. Match between system and real world
- Does information appear in a logical order for the user? - Does the design of the icons correspond to everyday objects? - Does every icon do the action that you expect? - Does the application use phrases and concepts familiar to the user?
3. User control and freedom
- Is there a link to come back to initial state or homepage? - Are the functions “undo” and “re-do” implemented? - Is it easy to come back to an earlier state of the application?
4. Consistency and standards
- Do link labels have the same names as their destinations? - Do the same actions always have the same results? - Do the icons have the same meaning everywhere? - Is the information displayed consistently on every page? - Are the colors of the links standard? If not, are they suitable for its use? - Do navigation elements follow the standards? (Buttons, check box, ...)
5. Error prevention
- Does a confirmation message appear before taking the action? - Is it clear what information needs to be entered in each box on a form? - Does the search engine tolerate typos and spelling errors?
6. Recognition rather than recall
- Is it easy to use the application for the first time? - Can you use the application at all times without remembering previous screens? - Is all content needed for navigation or task found in the “current screen”? - Is the information organized according to logic familiar to the end user?
7. Flexibility and efficiency of use
- Is it possible to easily perform an action done earlier? - Does the design adapt to the changes of screen resolution? - Is the use of accelerators visible to the normal user? - Does it always keep the user busy? (without unnecessary delays)
8. Aesthetic and minimalist design
- Is used a design without redundancy of information? - Is the information short, concise and accurate? - Is each item of information different from the rest and not confused? - Is the text well organized, with short sentences and quick to interpret?
9. Help users recognition, diagnose and recover from errors
- Does it display a message before taking irreversible actions? - Are errors shown in real time? - Is the error message that appears easily interpretable?
10. Help and documentation
- Is there the "help" option? - Is there a section of frequently asked questions (FAQ)? - Is the help documentation clear, with examples?

APPENDIX B

Activation
- Is a different learning approach like serious game can give an active environment in a classroom setting? - By using this application, the purpose in my classroom to create a supportive, challenging, and complex environment where questions are encouraged is achieved. - I can see the positives changes of my students behavior and performance while using this application
Clarify the outcomes that need to be achieved and the learning process involved
- The objective been preview to students so that they know briefly what they learnt that day. - This application easier for learning process takes place.
Making connection
- The topic is related with another? - My students can't answer the right question if they skip one topic
Carry out learning activities
- I utilize some form of brain-based learning strategy (e.g. students: drawings, charts, lists, dialogues, actions, demonstrations, debates, or mind-maps) on a weekly basis. - When playing an application, it give an opportunity for relax alertness learning environment which eliminated fears in the learner, while maintaining a highly challenging learning environment.
Demonstrating student's understanding
- This application is provided all the activities and exercise needed to achieved the learning objectives. - I feel that how one learns, plays an important role in classroom learning.
Review for students' retention
- Is this application allowing students to choose any topic to learn? - This game is enjoyable and can be repeating by students.
Preview the next topic
- This application pre-exposes my students to content & context of a topic before introducing it? - Showing what to learn help in reducing the fear and undesirable attitude and motivation amongst students taught.

Seamless Connectivity for Adaptive Multimedia Provisioning over P2P-enabled IP Multimedia Subsystem

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***Abstract*—The subsystem multimedia internet network (IMS) has been upgraded to support peer-to-peer content distribution services, the peer heterogeneity constraint imposes a challenge that is the guarantee of a certain level of QOS of the video for the different pairs, and the transfer poses a challenge for maintaining quality of service (QoS) in IMS. In this article, we we have extended a scalable Video Coding (SVC) peer-to-peer streaming adaptation model and our extension allows to add another parameter for this adaptation scheme which is the IP address of the peers, so to manage multiple network accesses to a peer when the user changes the type of access, due to a transfer or a loss of connectivity, this model is used to adapt the video quality to the static resources of the peers in order to avoid long start times, and to compare the results obtained for changing the type of network access, we performed two simulation scenarios, one with multiple peers that are connected to the network until the end of the video download by the peers and the other scenario with the change of the address of a peer during the operation of downloading the video sequence by peers. We quantified streaming performance using two metrics of evaluation (peak signal-to-noise ratio (PSNR)) and video quality metrics (VQM)), and also we extracted from the values of PLR (Packets loss rate). Our results show that our model has a better adaptation of the quality according to the network resources of the peers in term of bandwidth available in the network and the performances of the users (CPU, RAM, autonomy of the battery) and also allows a continuity of service in the network by ensuring that the list of peers is updated after each change. The results show a clear quality adaptation with heterogeneous terminals.**

***Keywords*—Next generation networks; NS2; quality adaptation; scalable video coding; peer to peer**

I. INTRODUCTION

The Internet Multimedia Subsystem has been standardized by the 3GPP [1] is used today as an architecture for triple-play services: telephony, Internet and video streaming. But streaming video requires a high cost in terms of equipment performance and bandwidth needed for better quality. Streaming in the IMS P2P network often uses data-oriented protocol in which, for example, each node periodically announces to its neighbors the blocks it has. Streaming in this network reduces the cost of infrastructure by taking advantage of customers to make content available and avoid having to set up important structures. The Internet Multimedia subsystem also supports peer-to-peer architecture, In [2] the authors propose to study and design a new content delivery network infrastructure, PeerMob, merging Peer-to-Peer technology with IMS, providing IMS with the scalability, reliability, and efficiency features offered by the decentralized P2P architecture and they put the P2P IMS system under real network conditions and a tough simulation to evaluate the performance of P2P IMS system. In [3] the authors proposed Nozzila a peer-to-peer video streaming service on the IMS network that can be used by IPTV service providers, Nozzila uses residential bridges to create a streaming overlay using the remaining or fixed bandwidth and it also takes advantage of the quality of service and resource reservation enabled by the NGN networks to support a multiple streaming description that improves perceived quality during temporary failures. In [4] the authors proposed virtual communities (VCs) in the IMS network and these virtual communities provide scope for the sharing service between end users in the mobile P2P network and allow them control of sharing. In [5], the authors proposed a framework for evaluating adaptive streaming performance based on SVC encoding, and they evaluated the metrics PLR and FLR versus time. Our research team has developed an algorithm adapting the quality according to the mobile. We could create a simulation of our adaptation model and connect it with the NS2 simulator to perform several simulations on a real flow following an architecture that groups the IMS network with P2P technology and for heterogeneous peers (PC, tablet, mobile), and we chose the use of H.264 / SVC coding that allows for multiplied distribution and adaptive streaming from a single file. On one hand H.264 SVC for Scalable Video Coding allows a video to be encoded with multiple quality layers in the same video file to be decoded gradually depending on the capacity of your internet connection and your device (PC, phone, laptop, etc. ...); With this extension, and into a single file, and in the same stream, are present different layers encoded in different resolutions (spatial) and quality levels (SNR / Quality / Fidelity), frame rate (temporal) and various combinations of these characteristics. SVC coding decodes the stream based on the capabilities of the device used, restriction of bandwidth and the speed of your connection. If we use a low-resolution video device will be decoded in low resolution, if your speed is low only the low-speed layer is decoded, if instead you have a broadband connection and a high-resolution device enjoy the best level of quality And after

we decided to extend this model with another parameter that is IP address of the peers to ensure continuity of service and keep the periodic update of the list of peers, and to compare the results obtained for changing the type of network access. We evaluated video packet transmission results. The rest of the paper is organized as follows. In Section II we present the background and in Section III We propose a scalable video streaming architecture in a P2P-IMS network. Section IV describes the simulation set up. In Section V we present the different results of the simulation. Section VI concludes the paper.

II. Background

A. Streaming Video in P2P IP Multimedia Subsystem (IMS)

Video streaming via peer-to-peer (P2P) networks using scalable video coding (SVC) for an NGN over the IP multimedia subsystem (IMS) is possible to implement, among the types of video streaming, there is video on demand and internet protocol TV. The P2P network can contain a heterogeneous architecture such as PC, tablet and mobile phone and can be connected to the network through different networks (LAN, ADSL, Wi-Fi) the constraint of heterogeneity of the pairs imposes a challenge which is to guarantee a certain level of QOS of the video for the different peers, the SVC coding proposes the solution of the coding by layer which makes it possible to divide the main flow into several sub streams while guaranteeing a fidelity to the original video, P2P streaming ensures scalability with existing demand, relying on the user's equipment to contribute their download bandwidth. Therefore, it represents an alternative cost-effectiveness to the client-server paradigm or more scalable architectures.

The objective of the Video Streaming Protocol in the P2P IMS Network is to serve as an enabling technology, taking advantage of the development experiences of existing P2P streaming systems. Its design will allow it to integrate with IETF protocols on distributed resource location, traffic location, streaming control and data transfer mechanisms to create a complete streaming system or a streaming infrastructure.

III. Proposed Architecture

Our proposed architecture is schematized in Fig. 1 and the screen capture of the NS2 simulation nam outpout is schematized in Fig. 2.

The main components of this architecture are: P-CSCF, I-CSCF, S-CSCF, the AS Tracker is an IMS application server that also performs tracker features. Its features include:

Stores a list of pairs and keeps it up-to-date based on the activity of user pairs and network pairs, and the sending of the list of pairs to UE, The AS Tracker collects a set of information from the UE. Our proposed architecture as shown in Fig. 1 is based on [6], we have an IMS network (which contains the P-CSCF, I-CSCF, S-CSCF) a server tracker that is connected to the IMS network and all the signaling messages between them, different peers and the server tracker passes through the IMS network, it is a model defined by 3GPP named P2P CDS architecture, this architecture essentially comprises the CSS entity (Content Source Server (CSS), the purpose of our approach more the technical coordination between IMS, P2P and Scalable Video Coding (H.264/SVC), is to benefit from the advantages of SVC coding to provide adaptive p2p streaming for the IMS network and in a heterogeneous architecture containing different devices (PC, tablet, phone). After the authentication step of the different clients at the level of the IMS network, the multimedia services become possible in the network. Our simulation will include the part of the SIP signaling in the IMS network of the different peers, the creation of a P2P network in our proposed architecture using the Zetasim [7] framework, and the part of the evaluation of the SVC coding using the myevalsvc [8] framework, in order to execute our SVC quality adaptation algorithm, we have developed our algorithm using C++ code, to choose the streamed stream that suits the performance of the peer, then we have to connect our C++ code with the TCL simulation (Tool Command Language) on NS2. Then we use the myevalsvc framework to evaluate the transmission of SVC encoding between two sending and receiving nodes. We use the zetasim framework for the creation of a P2P network and the download management of the video sequence and to simulate adaptive video streaming SVC between peers, the SIP module [9] is used for signaling in the network, where a peer plays the role of a server and other peers play the role of customers. Finally, we have created a complete architecture that can make the identification of IMS P2P users and which also allows the SVC adaptation of quality for heterogeneous devices.

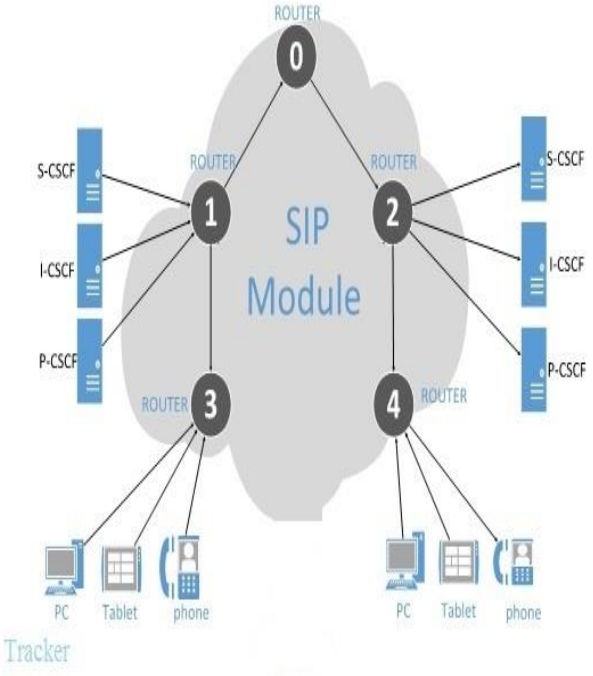

Fig. 1. Proposed Architecture.

Algorithm of adaptation

Algorithm: Selection of the appropriate SVC layer according to customer performance and access type

Input :
di=d0;
tj=t0 ;
qk=q0 ;
d0, t0, q0 represent three types of initial scalability.
Set the initial quality at the layer L0 (di,tj,qk) .
α ; The distribution of the video length in relation to the battery life.
β; Adaptive frame rate.
μ ; Adaptive level of SNR.
φ; Quantization parameter.
£; list of peer belonging to the network
@; address IP of the peer
dm ; Represents the maximum spatial scalability.
tm ; Represents the maximum time scalability.
qm ; Represents the maximum qualitative scalability.

Output :

Fulfill the constraints of the adjusted quality Ll (d,t,q)

Begin

For each level of the layer Ll,dm
If (Ll,di≤ User Preferences.Resolution Display)
then
level_SVC.add {di}
End if
End For

For each level of the layer Ll,(dm,tm)
If ((Ll,(di ,tj) ≤ User Preferences.Taux_Frame)

and (Ll,(di ,tj) ≤ Pair resources.bandwidth)
and (Bitrate(β, φ) ≤ Pair resources. bandwidth))
then
level_SVC.add {di,tj}
end if
end for

For each level of the layer Ll,(dm,tm,qm)
If ((Ll(di,tj,qk) ≤ User Preferences.level_SNR)
and (Ll(di,tj,qk) ≤ Pair resources.Device Power)
and
Complexity (di,tj,qk) ≤ Pair resources. Device Power (CPU)
and (α ≤1))
and @ ϵ £
then
level_SVC.add {di,tj,qk}
end if
end for

if level_SVC.add {di,tj,qk} is not empty
then Return the candidate of adaptive quality{d,t,q}
end if
Return "Error: static resources too low for the base stream"
end

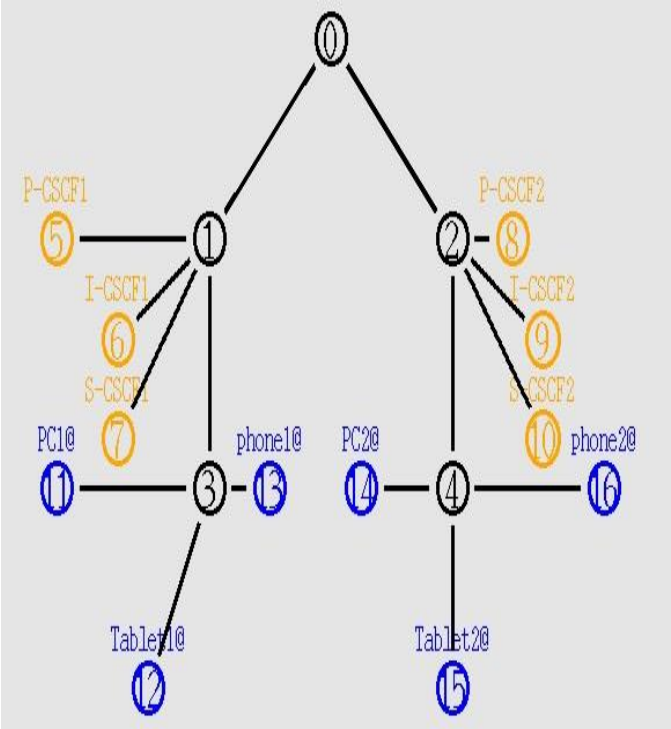

Fig. 2. Screen Capture of the NS2 Simulation Nam Outpout.

In Fig. 3, we present our model of quality adaptation, this model is extended from an existing model [10], by adding another parameter, which is the IP address of the user, in order to guarantee a continuity of service in the IMS P2P network, by ensuring an update of the list of peers after each change of IP address of the users following the model of Fig. 4, and we have created a C ++ code which simulates this model which aims to define the adequate quality (d, t, q) (spatial, temporal , qualitative) with the performance of the user, and we proceed as follows:

1) Executing the spatial adaptation, extracting the SVC levels that have the resolution of the appropriate video for the user according to the resolution parameter of the user's screen.

2) Taking into account the SVC levels already selected in step 1, the model executes the temporal adaptation according to the user requested frame rate and the network bandwidth to extract the levels of SVC respecting these conditions.

3) Taking into account the SVC levels already selected in step 2, does the model perform the qualitative adaptation, according to the user's preferences, does it request that the video be of quality or not, and respect also other more complex parameters that are: CPU performance, RAM, battery life to finally extract a single level SVC adapted to the performance of the user.

4) And taking into account the SVC level adapted to the performance of the user, a check of the IP addresses of the peers in the list of peers is performed, to ensure that the peer that will provide the video sequence is present in the list of peers.

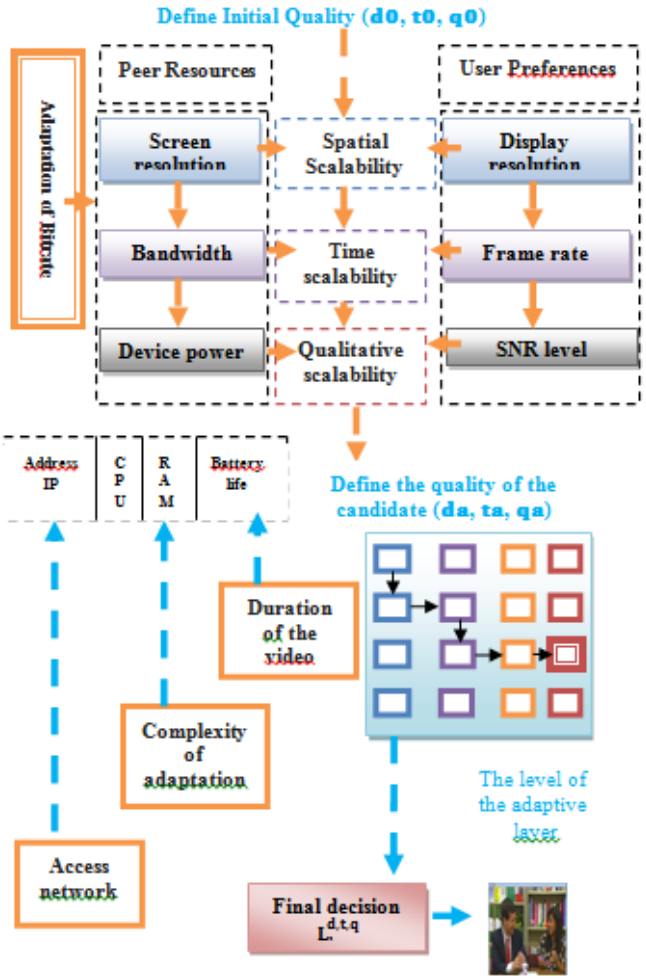

Fig. 3. Scheme of Adaptation Model.

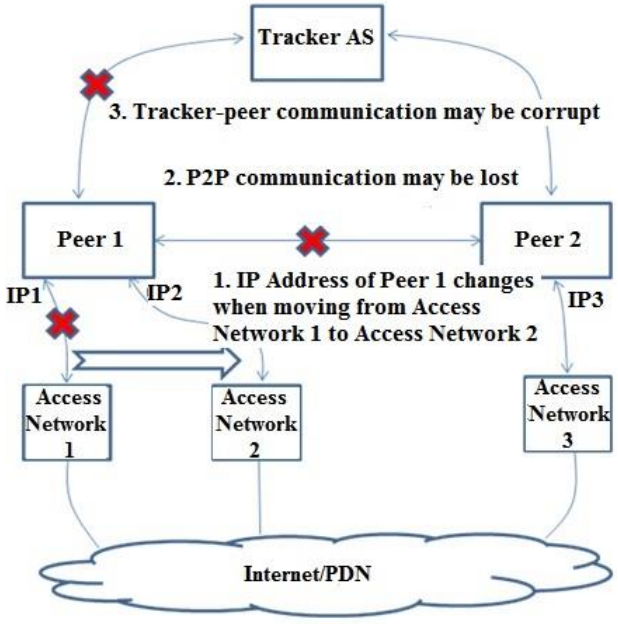

Fig. 4. Diagram Describing the Problem Addressed [6].

IV. Simulation Set-Up

We first evaluated two metrics of objective evaluation that are (peak signal-to-noise ratio (PSNR)) and video quality metrics (VQM)). Our test sequences are classified into two classes, PSNR vs. SVC layer level, VQM vs. SVC layer level. Then we simulated our proposed architecture, This simulation allows the SIP authentication of the different users then the creation of the sessions between the different clients, and the creation of a P2P network using the protocol zeta, then the execution of the code C ++ which allows to select the flow so that the peer only receives the appropriate sub stream with their performance and read the video with the appropriate quality, Then we use the myevalsvc framework to evaluate streaming performance in a heterogeneous architecture.

The architecture studied aims at evaluating Packet transmission delay, Packet size by transmission delay, Jitter, PLR (Packets loss rate). This architecture contains, IMS P2P network that contains heterogeneous peers. We will evaluate the video packets, while giving the transition time of these packets, and specifying the time of queuing. The output of the queue and the reception of the packet at its destination, the following results have been extracted:

- Packet transmission delay.
- Jitter by transmission delay.
- PSNR
- VQM.
- PLR (Packets loss rate).

The experiments have been performed on five video sequences and configuration that combining temporal, spatial and SNR scalable layers. Table I shows the configuration described in the main file of the JSVM encoder used for the selected sequences.

The coding parameters are shown in Table II.

TABLE. I. Test of Sequences

Video Sequence	QCIF Format	CIF Format	Number of frame	Number of layer
paris	176x144	352x288	1000	4
akiyo	176x144	352x288	300	4
Foreman	176x144	352x288	300	4
Hall Monitor	176x144	352x288	300	4
News	176x144	352x288	300	4

TABLE. II. Coding Parameters

Number of the layer	**4**
Base layer and enhancement layer resolution	176x144 ; 352x288
Encoded frames	1000 / 300
GoP size	8
Frame rate	30
Quantization parameter	36 ; 34 ; 30 ; 26
Encoding type	MGS

TABLE. III. CONFIGURATION OF PARAMETERS OF THE SVC VIDEO USED IN THE SIMULATION

Configuration Files	The settings	Values
Main.cfg	FrameRate	30
	FramesToBeEncoded	1000 / 300
	GOPSize	8
	NumLayers	4
Layer0.cfg	SourceWidth	176
	SourceHeight	144
	FrameRateIn	30
	FrameRateOut	30
	QP	36
Layer1.cfg	SourceWidth	176
	SourceHeight	144
	FrameRateIn	30
	FrameRateOut	30
	QP	34
Layer2.cfg	SourceWidth	352
	SourceHeight	288
	FrameRateIn	30
	FrameRateOut	30
	QP	30
Layer3.cfg	SourceWidth	352
	SourceHeight	288
	FrameRateIn	30
	FrameRateOut	30
	QP	26

Table III shows the configuration of the main parameters used for SVC videos by JSVM in the simulation; note that each SVC layer is divided into 4 sub-layers.

V. RESULTS AND ANALYSIS

A. PSNR

We performed the required configuration in JSVM to enable the scalability mode for the tests videos used "paris", “akiyo”, “Foreman”, “Hall Monitor”, “News”, the reconstructed scalable substreams are compared with the original stream containing all the sub-layers. Table IV shows the average of the PSNR coded for each layer level, these values are shematized in Fig. 5.

According to Table V, the scalability in sequences quality takes the three different values of the spatial, temporal and quality named identifiers represented by (D, T, Q) respectively for each SVC level (Sub-layer or index -layer).

TABLE. IV. PSNR BY SUB-LAYERS

Layer level	PSNR average for sub-layer (paris)	PSNR average for sub-layer (akiyo)	PSNR average for sub-layer (Foreman)	PSNR average for sub-layer (Hall Monitor)	PSNR average for sub-layer (News)
0 ;4 ;8 ;12	25,48	24,40	19,93	24,37	20,64
1 ;5 ;9 ;13	26,00	24,40	19,54	23,97	20,39
2 ;6 ;10 ;14	26,57	24,71	19,58	24,16	20,45
3 ;7 ;11 ;15	37,99	33,21	32,55	31,32	31,70

TABLE. V. CODING PARAMETERS

Sub layer	(Lid,Tid, Qid)	Frame Rate	Bit rate (kbps)				
			PR	AK	FR	HM	NW
0	(0,0,0)	3.75	105.2	571.3	1147	1147	861
1	(0,1,0)	7.5	112.4	580.4	1172.4	1166.3	878.9
2	(0,2,0)	15	120.1	582.1	1183.8	1170.3	885.4
3	(0,3,0)	30	127.8	584	1195.6	1174	891.1
4	(0,0,1)	3.75	141.4	572.3	1147.7	1147.7	861.8
5	(0,1,1)	7.5	153.3	582.6	1178.2	1169.1	882.8
6	(0,2,1)	15	167.8	586.1	1197.3	1177.3	894.2
7	(0,3,1)	30	182.5	590.7	1219.2	1185.6	905.9
8	(1,0,0)	3.75	725.1	2632	5734	5734	3989
9	(1,1,0)	7.5	769.8	2686	5917	5898	4099
10	(1,2,0)	15	816.3	2707	6047	6002	4170
11	(1,3,0)	30	860.7	2728	6199	6119	4230
12	(1,0,1)	3.75	1036.3	2634	5735	5735	3990
13	(1,1,1)	7.5	1118.2	2705	6030	6094	4144
14	(1,2,1)	15	1206.5	2747	6316	6434	4281
15	(1,3,1)	30	1294.3	2792	6629	6774	4398

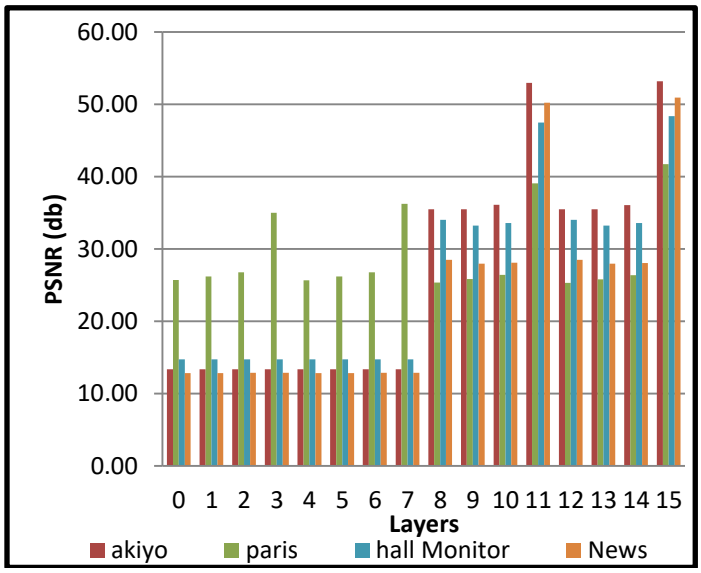

Fig. 5. PSNR (db) Versus Layers.

B. VQM

Our tests sequence was subjected to VQM that makes a comparison between the original video sequence and the distorted video sequence, based only on a set of features extracted independently from each video. The values of VQM are shematized in Fig. 6 evaluates the performance of the zetasim framework, we performed simulations for different numbers of peers (10,30,50 and 70 pairs), based on the simulation parameters of Tables VI and VII and we obtained the results schematized in Table VIII and Fig. 7.

First we calculate the estimated time for a peer to join the P2P network as shown in Table IX, after we performed two simulation scenarios, one with multiple peers that are connected to the network until the end of the video download by the peers and the other scenario with the change of the address of a peer during the operation of downloading the video sequence by peers.

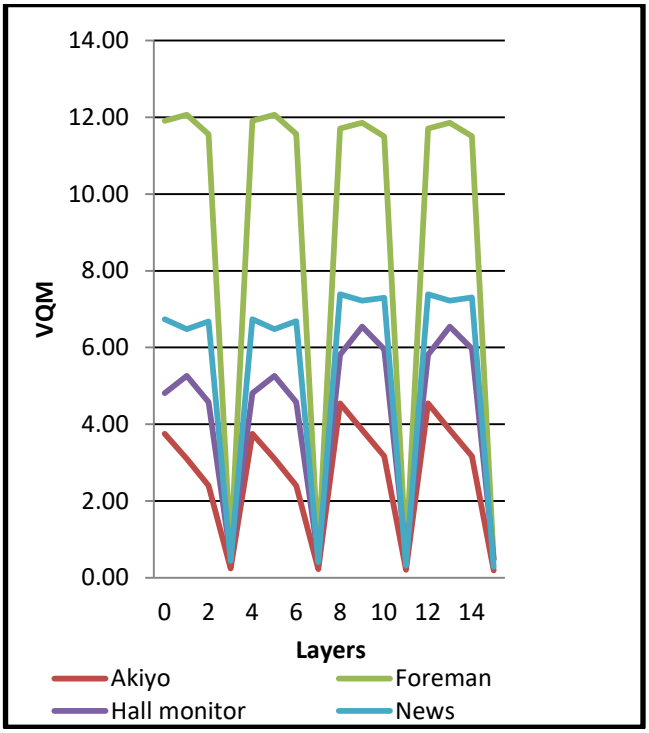

Fig. 6. VQM Versus Layers.

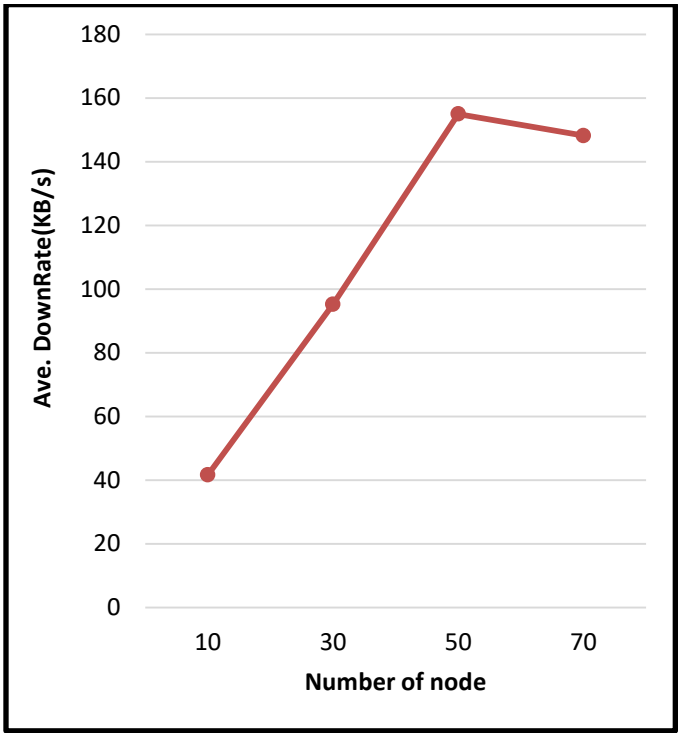

Fig. 7. Averge Download Rate Versus Number of Node.

TABLE. VI. THE SIMULATION PARAMETERS

Simulation parameter	Value
Link type	duplex-link
Bandwidth (PC)	10MB
Bandwidth (Tablet)	5 MB
Bandwidth (Phone)	1.5 MB
Queuing time	5ms,2 ms
Packet scheduling type	DropTail

TABLE. VII. THE SIMULATION PARAMETERS

Simulation parameter	Value
Tracker	Boot server and tracker
number of bootserver	1
Update peers interval of peer node	0.5 s
tracker_threshold	3
Maximum size NSSocket packet	3
maxUploadSpeed	100kb
code word size	1
block size	20KB
total size of the file	3Mb
threshold to start seeder	0.5
Simulation duration	100

TABLE. VIII. SIMULATION RESULTS FOR DIFFERENT NODES

Number of Nodes	Ave. Down Rate(KB/s)	Ave.Query Time(s)
10	41,694 KBps	0,03408 s
30	95,236 KBps	0,03408 s
50	154,97 KBps	0,03408 s
70	148,16 KBps	0,03408 s

TABLE. IX. THE ESTIMATED TIME FOR A PEER TO JOIN THE P2P NETWORK

Packet	Time (s)
CONNECT_BOOT_SERVER	0,00948
CONNECT_BOOT_SERVER_REPLY	0,009
UPDATE_SHARED_FILES	0,03764
Update Shared Files has been Acked	0,00668
Total	0,0628

Following Fig. 8, the simulation showed that the change of the peer's address allowed an increase of the average download rate in KB/s, which shows the utility of our adaptation model.

Fig. 8. Average Download Rate by One Peer for the Case of Change of Address and Without Change of Address.

The adaptation of the quality can be schematized by the following expression:

$$\text{Bitrate}(QP,T) = B_{max}\left(\frac{QP}{QP_{min}}\right) - a\left(\frac{T}{T_{max}}\right) b$$

Expression I : Adaptation of bitrate.

Where the maximum bitrate is:

B_{max} = Bitrate (QP_{min},T_{max}),**a** and **b** are known and constant parameters dependent on QP_{min} and T_{max}[11].

For simulating streaming video at the NS2 simulator, we used the Soccer sequence which is of type 4CIF (with a resolution of 704x576) (which has duration of 90 seconds) and which was coded in 14 sub-layers and a frame rate 30 fps and 3 level of quality, we compared the transmission results of video packets in and we found the results schematized by the following figures.

From Fig. 9, note that the average of the transmission delay is at most for the number of packets equal to 48, the minimum value of the transmission delay average is for the number of packets equal to 51, between the number of packets 2 and 50, There is a simple change in the values of the transmission delay average and for the packet numbers of 50 or more there are a significant change differences in the mean transmission delay values.

From Fig. 10, note that we have several jitter values for transmission delay of video packets.

To check the performance of our adaptation algorithm, we performed a streaming comparison to a client that has the rate of the SVC 9 level, and we sent to it the global sequence, then we sent to it the appropriate sequence with the level SVC 9, and we extracted the values of PLR of both cases. The results are shown in Fig. 11.

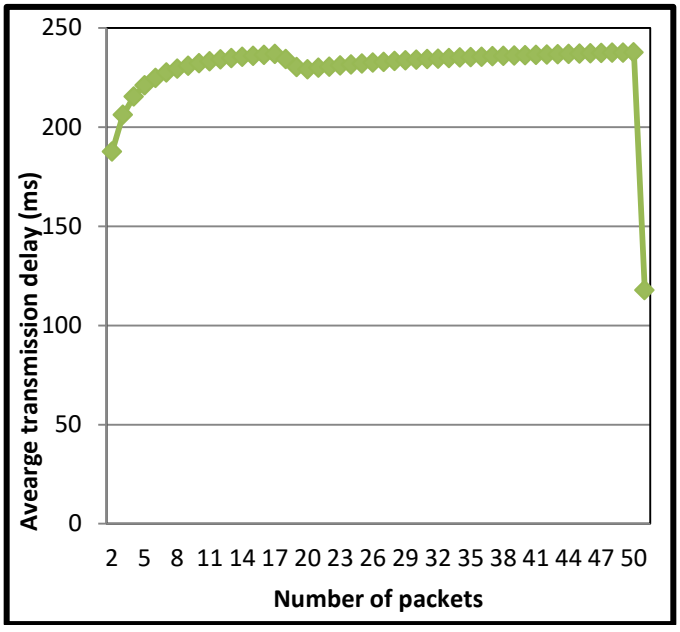

Fig. 9. Average End-to-End Transmission Delay on the Number of Video Packets.

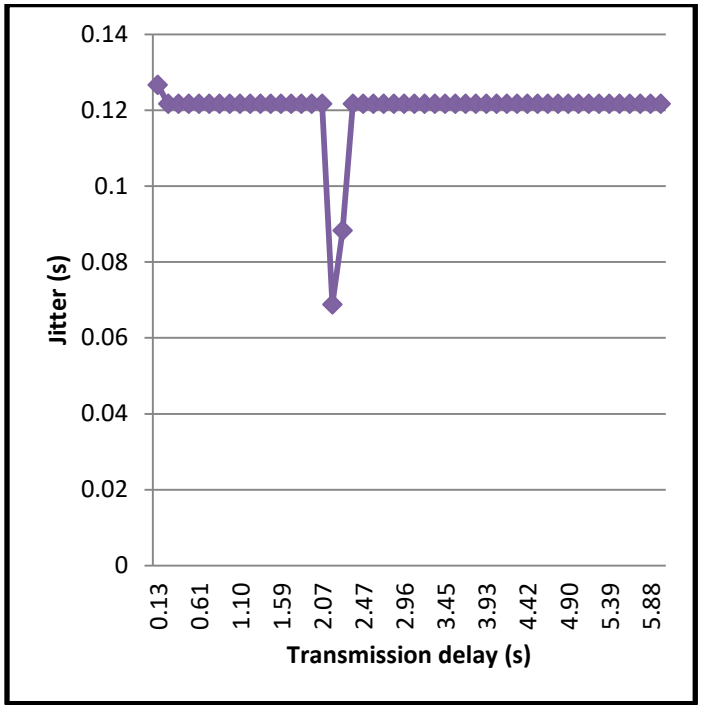

Fig. 10. Jitter on Transmission Delay of Video Packets

From Fig. 11, note that our simulation model allowed a very low level of PLR.

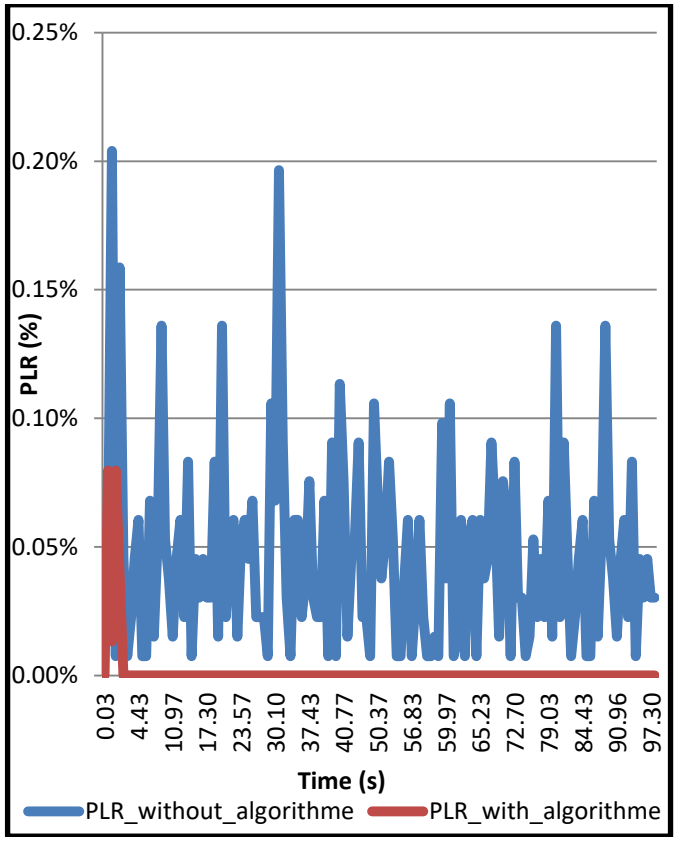

Fig. 11. Comparison between the Rate of Loss of the Packets with the use of the Algorithm of the Adaptation and without the use of the Algorithm.

C. Comparative Analysis with Latest Research Work

To check the performance of our adaptation algorithm, we performed the streaming using the framework avis [5], and we found the results schematized in Fig. 12.

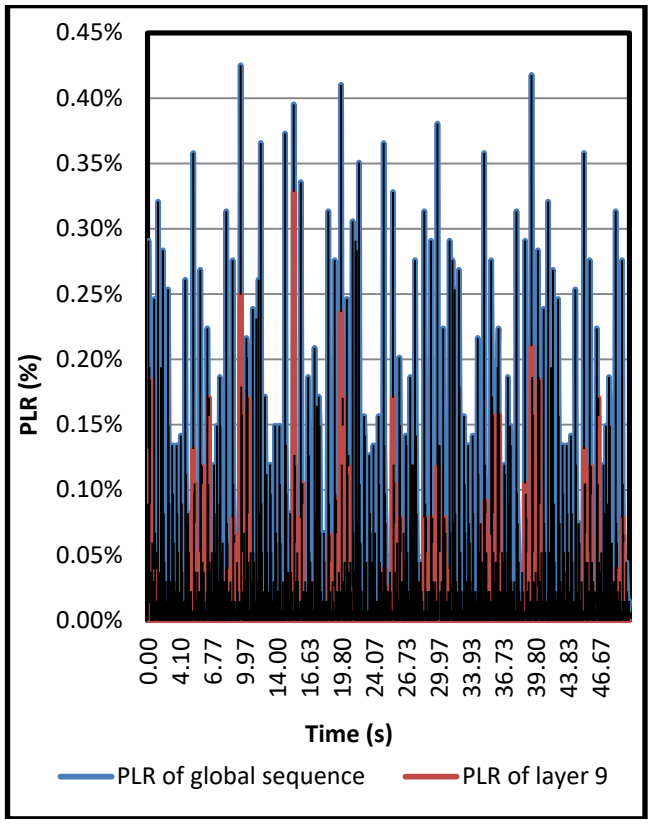

Fig. 12. Comparison between the Loss Rate of the Packets with the use of the AVIS Framework for the Global Sequence Containing All the Layers and the Sequence of the Layer 9.

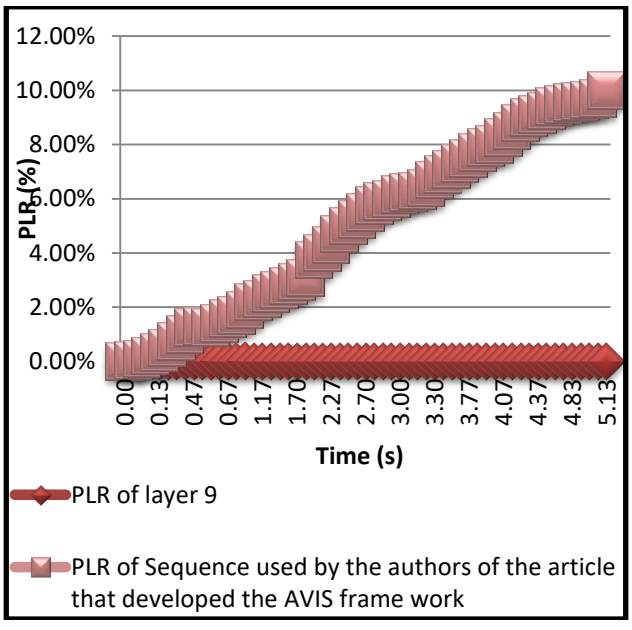

Fig. 13. Comparison between the Loss Rate of the Packets with the use of the AVIS Framework for the Streaming of our Sequence of the Layer 9 and the Streaming of the Sequence used by the Authors of [5].

Our results show that our model has a better adaptation of the quality according to the network resources of the peers in term of bandwidth available in the network and the performances of the users (CPU, RAM, autonomy of the battery), since the rate of packet loss achieved by our adaptation algorithm is less than the packet loss rate achieved by the authors of the article that developed the AVIS frame work as shown in Fig. 13 and also our model allows a continuity of service in the network by ensuring that the list of peers is updated after each change.

The limitation of the study is that we have not tested the performance of our adaptation model in real Internet structure based on a more powerful peer-to-peer protocol that manages gigantic p2p networks.

VI. Conclusion

This paper presented a quality adaptation by scalable video streaming over P2P IMS network. The simulation was tested in NS2 and performed using the code C++ of NS2 SIP, myevalsvc. The results show a clear quality adaptation with heterogeneous terminals, and show the importance of continuity of service for p2p networks. The proposed quality adaptive scheme is also responsive to available network bandwidth and the change of access network of peers.

VII. Future Work

Future work will take into account the advances of H.264 SVC codec in the proposed implementation of adaptive streaming algorithms in both TCL and C++ domains, and the test of the performance of adaptation model in gigantic p2p networks managed by strong peer-to-peer protocol.

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Cas-GANs: An Approach of Dialogue Policy Learning based on GAN and RL Techniques

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***Abstract*—Dialogue management systems are commonly applied in daily life, such as online shopping, hotel booking, and driving booking. Efficient dialogue management policy helps systems to respond to the user in an effective way. Policy learning is a complex task to build a dialogue system. There are different approaches have been proposed in the last decade to build a goal-oriented dialogue agent to train the systems with an efficient policy. The Generative adversarial network (GAN) is used in the dialogue generation, in previous works to build dialogue agents by selecting the optimal policy learning. The efficient dialogue policy learning aims to improve the quality of fluency and diversity for generated dialogues. Reinforcement learning (RL) algorithms are used to optimize the policies because the sequence is discrete. In this study, we have proposed a new technique called Cascade Generative Adversarial Network (Cas-GAN) that is combination of the GAN and RL for dialog generation. The Cas-GAN can model the relations between the dialogues (sentences) by using Graph Convolutional Networks (GCN). The graph nodes are consisting of different high level and low-level nodes representing the vertices and edges of the graph. Then, we use the maximum log-likelihood (MLL) approach to train the parameters and choose the best nodes. The experimental results compared with the HRL, RL agents and we got state-of-the-art results.**

Keywords*—Generative Adversarial Networks (GANs); Graph Convolutional Network (GCN); Reinforce Learning (RL); Dialogue policy learning; Maximum Log-Likelihood (MLL)

I. Introduction

The task-oriented systems are used for interacting between user and the system using dialogues, that can be texts or spoken words. The response from the system is very important to know the good response of the trained system or agents. Efficient dialogue management policy help systems to respond to the user in an effective way. Meanwhile, end to end dialogue management agents are also known as dialogue agents or conversational agents. In dialogue management systems [1], the user interacts with the system by using the dialogues to train the task-oriented dialogue systems [2].

Typically, the experts design a dialogue management policy manually. The manual dialogue management policy is more time consuming, and it needs more cost to build the policy for the management system. Moreover, users want to get the output from the agent during the conversation. This research work relates the GAN with RL techniques to improve the dialogue policy learning in the dialogue management systems.

Reinforcement learning (RL) algorithms are used to optimize the policies because the sequence is discrete. The reinforcement learning mechanism is consisting of some states and corresponding actions. The generative adversarial networks (GANs) are used to train the dialogue policy learning, that is consisting of two networks, generator and the discriminator. The generator is responsible for generating the fake data and the discriminator is responsible for choosing the best reward from real and the generated data. The discriminator network issues a reward to inform the generator for generating a more realistic response. The discriminator network takes a dialogue consisting of a context-reply pair as input and outputs the probability which shows that the dialogues are coming from the real dialogues. There are many model-based evaluation methods used such as policy evaluation method. There are many model's free RL algorithms such as the Q-learning, SARSA, Dyna-Q and the temporal difference (TD).

The RL approach is more data-driven, because it trains the actions as the function of the states. Much research has been done to improve [3] the dialogue systems as well as the dialogue policy gradient [4]. The policy gradient is a policy method to train models that allow automatically generate the system response according to the trained model. The NN models play a key role to train such policy gradients, CNN, and RNN [5] to improve the training. Reinforcement learning (RL) algorithms are popularly used to solve the major problems in the task-oriented dialogue systems [6] to interact with the users. The general model of RL consists of three components are: (1) the state denoted by 's'; (2) the action denoted by 'a'; (3) the reward denoted is by 'r'. The policy is the rule that specifies how to choose an action. The action is depending on the awarded reward to verify the output either it is good or bad. Using a recurrent neural network (RNN) is making a significant improvement to learn the management policy [7] for helping the better system response. Recently, the GCN is used to learn the features through the functions in a graph. Also, GCN can be used to train the efficient management policy by working with the GAN.

The proposed approach (Cas-GAN) includes the general RL and GAN structure. The result shows the improvement when we trained the dialogue agent for operating dialogues using GANs platform using the proposed approach. The task-oriented systems are used for interacting between the user and the system. Users are able to interact with the system by using dialogues, and that can be texts or spoken words. The good response from the system is very important to know the quality of the trained system or agents. Efficient dialogue management policy help systems to respond to the user in an effective way.

The rest of this paper is structured as follows: related work in Section II. Section III introduces the methodology of the study. Section IV the proposed work. Section V explains the implementation. Results and analysis in Section VI. Finally, the conclusion and recommendation in Section VII.

II. Related Work

To train dialogues policy for user-system interaction (DMS), Satinder Singh and his team [8] have trained a spoken DMS that provides information to go for outing or do fun in New Jersey for users. The results show that the performance of the trained NJFun dialogue system was effectively improved. The NJFun dialogue system was implemented to give telephone access from the database of activities in New Jersey. Dialogue policy learning they define a state-based representation for dialogues. The results show the increasing number of completed dialogues from 46 % to 69 % during the training and that considered as the significant improvements for several reward measures.

A statistical model to perform real-time policy learning in the spoken dialogue management systems and updating of dialogue states has been proposed by Blaise Thomson [9]. This framework is based on POMDP it provides a well-established statistical model of the spoken DMS. A spoken DMS was proposed to allow users for better decision making. Which bridged the gap between the user's criteria, and if not found responded with an alternate [10].

Another proposed model of dialogue state considers the user preferences as well as the user knowledge about the domain transferring from restaurant booking to car booking. The result shows that the learned policy works better than several baseline methods. The recent work used NN models [11] for generating dialogues, and that shows much improvement and efficient responses for conversational agents. But modeling the future responses regarding dialogues are very crucial. Also, that demands the use of traditional NLP models of dialogue with the help of RL. The proposed policy gradient method works better because it initializes the encoder, decoder, and RNN using the MLE parameters.

The DMS builds a dialogue agent that can fulfill the desired complex tasks is much challenging because of different multiple subtasks such as travel planning. The dialogue manager is consisting of a high-level dialogue policy able to selects between subtasks. The low-level policy selects the required actions to complete the subtasks received from the high-level policy. The end-to-end dialogue model architecture [12] consists of the user utterances, the LSTM dialogue state, also the slot values, policy network, and the system action. They apply the REINFORCE algorithm to optimize the network parameters and used soft-max policy during RL training to encourage the agent to explore the dialogue action space.

The GANs has been recently applied to Neural Machine Translation system (NMT). Zhen Yang builds a conditional sequences GAN [13] consisting of two adversarial sub-models the generator and discriminator. Each one was able to respond and generate sentences that were hard to discriminate from human translated sentences. Discriminator was also used to discriminate the machine-generated sentences from human translated sentences. The GANs sentence level BLEU is utilized as the reinforce objective for the generator, and biases the generation towards high BLEU points. The proposed model presents a divide and conquers method that discovers the hidden structure of the tasks to enable effective policy learning.

Da Tang proposed Sub-goal Discovery Network [14] to divide the complex goal-oriented tasks into sub-goals in an unsupervised way. Moreover, they present a dialogue agent for the composite task of travel planning. There are two processes used to train the dialogue agent. One is a high-level process that selects the sub-goals to complete, and second is a low-level process that chooses the primitive actions to accomplish the selected objective sub-goals. The experiment results show the learned agent performs efficiently against an agent learned using expert-defined sub-goals. The sub-goal discovery trained by using RNN model has been carried out by two RNN models used in this approach, RNN1, and RNN2. RNN2 provides information about previous states from RNN1. To train SDN, RMSProp has been used to optimize model parameters. The result shows better performance as compared to the state-of-art baseline models.

III. Methodology

We have proposed a new approach for dialogue policy learning and introduced the Cascade Generative adversarial network (Cas-GAN). In this approach, the generator part is responsible for the training of the policy by using GCN and RL techniques. The generator is responsible for generating the fake data and the MLL technique is used to calculate the generator value [15]. The discriminator is responsible to learn the strategies by using the MCS and it will generate a reward which is depending on the value from 0 to 1. The reward values 0 and 1 are representing the bad and good reward. This approach will lead to efficient dialogue policy learning to allow users to find desired search results more accurately in a short time by interacting with the RL [16] based on the generated system.

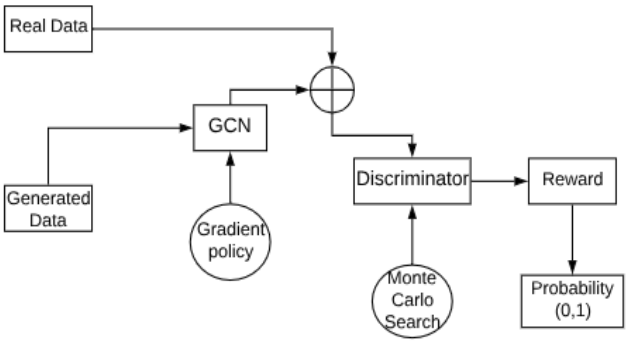
IV. Proposed Work

To train the task-oriented dialogue systems the dialogue policy plays a vital role. If dialogue policy is learned efficiently that lead to effective results in the responding system [17]. Typically, the experts design a dialogue management policy by hand that is more time consuming and needs more cost. Recent research has suggested that efficiently learned policy using formalisms of RL and the MDP. RL algorithms are popularly used to solve the major problems in task-oriented dialogue

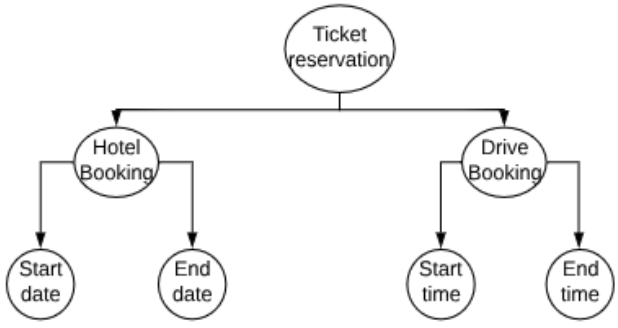
systems. The general model of RL is consisting of three components are (1) the state denoted by s; (2) the action denoted by a; (3) reward denoted by r. The policy is the rule that specifies to choose an action the level of action good or bad is depending on the awarded reward. The architecture in Fig. 1 shows the generator has been trained with fake data. Moreover, policy learning is also learned within the generator. The policy has been learned by GCN and RL techniques, and we have followed the general architecture of RL that is consisting of some states and actions. Depending on these actions the reward will be issued to the system to checking user satisfactory to reach the goal, for example, booking air ticket and hotel reservation or taxi drive booking. The discriminator is responsible for choosing the best reward for the system response, and there are several methods have been used to train the discriminator. We have used the reinforce algorithm along with MCS for choosing the best reward.

The proposed technique shows that we have used GCN to learn the gradient policy for better system response. The discriminator will use MC search method to choose the best reward according to the user search query.

The dialogue sequence generation is a common problem to overcome this challenge, we have used structured dialogue sequences dataset to train a parameterized θ generative model Gθ for generating the sequence G1: T = (g1..., gt, T), the capital G denotes the vocabulary for the candidate tokens. We have considered a policy learning problem in RL based scenario. In time step t, the states are the currently produced tokens (g1..., gt−1). Whereas, the action 'a' is the next token yt to be selected. The policy model is stochastic that is denoted by Gθ (gt|G1: g−1).



(a) Architecture of Cas-Gan.



(b) Description of Graph Nodes.

Fig. 1. Visualization of Cas-GAN.

We have trained a φ-parameterized discriminative model Dφ, to provide the guidance for improving generator Gθ for dialogue generation [18]. Where Dφ (G1: T) is the probability indicating the likelihood of a required dialogue G1: T from real data or the generated data. The discriminative Dφ has been trained by giving positive utterances from the true sequence dialogue data, and negative examples from the synthetic sequence dialogues that are generated by the generative model Gθ. On the other hand, generative Gθ has been updated by learning a policy gradient also MCS is used for the expected rewards to be received from the discriminative model Dφ. The reward is calculated by the likelihood estimation and that shows how successful it can fool the discriminative model Dφ. The problem of classifying nodes in a graph can be denoted as graph-based semi-supervised learning shows the information of labeling the data is very smoothed over the graph via some form of explicit graph-based regularization [19]. We have used a graph Laplacian regularization. The loss function can be defined as:

$$\mathcal{L} = \mathcal{L}_0 + \lambda \mathcal{L}_{reg},\ with\ \ \mathcal{L}_{reg} = \sum_{i,j} A_{ij} ||f(X_i) - f(X_j)||^2 = f(X)^T \Delta f(X) \quad (1)$$

In Eq (1), L_0 denotes the supervised loss w.r.t the labeled part of the graph, and f (·) is a NN differentiable function. However, the λ is a weighting factor, and X is a matrix of node feature vectors, Xi = M- N denotes the unnormalized graph Laplacian of an undirected graph G = (V, E) with the nodes N∈ V, edges (vi, vj) ∈ E, adjacency matrix A ∈ R, N×N (binary or weighted) and degree matrix M_ii = A_ij. The formulation is based on the supposition to connect the nodes in the graph that are likely to share the same label. The assumption may limit the modeling capacity that the graph edges do not need necessarily encode node similarity but it may contain the additional information.

The objective of the dialogue policy learning Gθ (yf|Y1: f−1), to train or develop a dialogue sequence from the starting state s0 for maximizing the expected reward. Eq (2) defines the form to complete a sequence of dialogue utterance.

$$J(\theta) = \mathbb{E}[R_T | s_0, \theta = \sum_{y1 \epsilon Y} G_\theta(y1|s_0).\, Q_{D_\theta}^{G_\theta}(s_0, y1) \quad (2)$$

In Eq (2), R_T is the reward for a complete sequence of dialogue utterance and values of reward comes from the discriminator. Q_(D_θ)^(G_θ) (s,a) is the action-value function of a sequence which is consists of a generator and the discriminator of the GAN network. The expected accumulative reward is starting from the state (s) taking action (a) and followed by the policy Gθ. The rationale of the objective function for a sequence is starting from a given initial state. The goal of the generator is to generate a dialogue sequence such as (i.e. If the user wants ticket reservation for different countries or the user wants to book the hotel at the same time the user can also select to reserve the car driving. In all this scenario the system should give an efficient response and that is following by the discriminator reward to consider if it comes from the truth data [20]. The question is how we can estimate the action-value function. To overcome this problem, we used the REINFORCE algorithm that will consider the estimated probability of being real from the discriminator Dφ (Y n1: T) as the reward value.

$$Q_{D_\theta}^{G_\theta}(a = y_T, s = Y_{1:T-1}) = D_\emptyset(Y_{1:T}) \quad (3)$$

Although we can get the reward value from the discriminator for finished dialogue sequence utterance we further focus on the long-term reward. At every time step, we don't focus only on the fitness of previous tokens but also on the future resulted in the outcome. It is the same to play the Go or Chess games show the players can end up the immediate interests sometimes for the long-term win. For the evaluation of value-based rewards to a corresponding state, we used MCS with a roll-out policy Gβ, to sample the unknown last T −t tokens [21].

$$\{Y_{1:T}^1, \ldots, Y_{1:T}^N\} = MC^{G_\beta}(Y_{1:f}; N) \quad (4)$$

In Eq (4), 〖 Y〗 _m1: t = (y1... yt) and Y n t+1: T is depending on the roll-out policy Gβ, and the current state. In this work, Gβ is set the same as the generator. To overcome the variance and find the efficient result from the action-value we trained the roll-out policy starting from the current state until the end of the dialogue sequence utterance for N times batch samples of the output.

$$Q_{D_\theta}^{G_\theta}(s = Y_{1:f-1}, a = yt) = \{D_\emptyset^{\frac{1}{M}} \sum_{m=1_{(Y1:f)}}^{N} D_\emptyset(Y_{1:T}^m \in MC^{G_\beta}(Y_{1:f}; M) \begin{matrix} for & f < T \\ for & f = T \end{matrix} \quad (5)$$

In Eq (5), there is no immediate reward. The function is iterative, and the next state value is starting from the state's' = Y1: f, and rolling out to the end. The purpose of using the discriminator Dφ as a reward function can be dynamically updated to the required improvements of the generative model. Thus, once we get a set of more true generated dialogue utterances and we should train the discriminator model again from the Eq (6).

$$\min_\emptyset -\mathbb{E}_{Y\sim p_{data}}[\log D_\emptyset(Y)] - \mathbb{E}_{Y\sim G_\theta}[\log(1 - D_\emptyset(Y))] \quad (6)$$

When we obtain a new discriminator model D_∅, we are also ready for updating the generator G_θ for next utterance. The method of gradient policy learning depends on optimizing a parametrized policy to directly maximize the long-term reward. The gradient of the objective function J(θ) w.r.t. the generator's parameters θ.

$$\nabla_\theta J(\theta) \mathbb{E}_{Y_{1:f-1\sim G_\theta}}[\sum_{yf\in Y} \nabla_\theta G_\theta(yt|Y_{1:f-1}).Q_{D_\emptyset}^{G_\theta}(Y_{Y1:f-1,yf})] \quad (7)$$

Eq (7) is representing the deterministic state transition and the zero intermediate rewards. By using the likelihood ratios, we have built an unbiased estimation shown in Eq (8, 9).

$$\nabla_\theta J(\theta) \simeq \frac{1}{T}\sum_{f-1}^{T}\sum_{yf\in Y} \nabla_\theta G_\emptyset(yf|Y_{1:f-1}).Q_{D_\emptyset}^{G_\theta}(Y_{1:f-1,yf})$$

$$= \frac{1}{T}\sum_{f=1}^{T}\sum_{yf\in Y} G_\theta(yf|Y_{1:f-1})$$

$$\nabla_\theta log G_\theta(yf|Y_{1:f-1}).Q_{D_\emptyset}^{G_\theta}(Y_{1:f-1,yf}) \quad (8)$$

$$= \frac{1}{T}\sum_{f=1}^{T} \mathbb{E}_{yf\sim G_\theta(yf|Y_{1:f-1})}$$

$$[\nabla_\theta log G_\theta(yf|Y_{1:f-1}).Q_{D_\emptyset}^{G_\theta}(Y_{1:f-1,yf})] \quad (9)$$

Y1: f−1 is the learned state that is sampled by the Gθ. Moreover, the expectation E [·] can be approximated by sampling the methods and we can update the generator's parameters in Eq (10).

$$\theta \leftarrow \theta + \alpha_h \nabla_\theta J(\theta) \quad (10)$$

The α_ (h)∈ R+ indicates the learning rate, corresponding at the h-th step. We can also use advanced gradient algorithms, such as Adam and RMSProp.

V. Implementation

In order to test the efficiency and the understanding of Cas-GAN, we have pre-trained the data in the generator network by using the dataset of dialogue sequences. For simulating the real-world structural dialogues, we used a model of language to indicate the dependency for the free slots by issuing tokens.

In order to set the experiment, we first initialize the parameters of a GAN network, followed by the normal distribution between different states denoted by N (0,1). The normal distribution helps to distribute the data by using MLE [16]. The generated data along with the real data are being concatenated under the mechanism of GAN. We used G oracle to generate dialogues of length 15 to 20, for the training set S to the generative models. The occurrences are depending on the number of turns, also the system and user takes to finish one whole dialogue in different frames. In the training set for the discriminator, the reward is representing from 0 to 1 that indicates the quality of the response sent to the system. By follows the reward, the generator is learning more efficiently to response the user queries. And try to choose the best matching dialogue sent to the discriminator using Monte Carlo search [22]. For different tasks to be performed, we must design some specific structures for the convolutional layer. In this experiment, the kernel size is from 1 to T and the number of each kernel size is between 100 to 2004. The dropout and L2 regularization are used to avoid over-fitting.

The learning process of the new technique shows better performance when we are comparing the results with the previous technique HRL, RL and Rule. In the training process, the number of turns is changing from the frames to get the true previous tokens, also from one state to another followed by the desired query of the user. Curriculum rate ω is used to overcome the problem for the probability by replacing the true tokens with the generated ones. To get stable and effective performance, we decreased ω by 0.002 for every training epoch that gives a good probability rate. We have used BLEU [23] as standard to measures the similarity from the real and generated reward for scoring the finalize samples from Monte Carlo Search.

The experimental dataset for this experiment is used to train the policy for the GANs, by using RL platform. The publicly available multi-domain dialogue corpus called Q/A frames dataset [24] have been used in this experiment. The dataset

provides the basic knowledge for generating the data, also the discriminator can distinguish between the real and the generated data by the generator. We used the epochs size 200 for the adversarial pre-training and 115 for pre-training the generator. There is 1369 total number of dialogues that have divided into different frames, and 268 hotels from 109 cities. The average user satisfaction rate is 4.58 regarding bad, average, good, very good, and excellent that is representing from 1 to 5 respectively. The number of turns for the whole dataset is 19986.

This dataset includes three types of dialogues are (1) flight reservation; (2) hotel reservation; (3) the driving reservation. This dataset is prepared by domain experts and publicly available on the Maluuba website. There are different representations of the dataset that are including (1) the number of occurrences according to action names; (2) turns per number of actions; (3) dialogue act frequency according to the number of dialogue act frequency; (4) the number of frames and ratio of frames changes; (5) dialogue length distribution according to number of turns for per dialogue length. User and system or wizard occurrences also the representation for package comparisons of frames and the linear frames comparison.

The other dialogue corpus dataset is also available, and most of them are consisting of the datasets of movie booking or the restaurant booking. For all these datasets the interaction between the user and the system is important because these datasets purely prepared for the chatbot systems. The used dataset provides more information about the travel booking, hotel booking, and drive booking. The representation of the data is showing the distribution of the dataset, and the distribution of the frame information. The most commonly used occurrence used is 'inform' when the user or system is interacting with each other using some dialogues. The first action performed is to inform the state and performed a suitable action according to the user information.

VI. Results and Analysis

The epoch size is defining as 200 for adversarial pre-training, and 115 for pre-training the generator. There is 1369 total number of dialogues divided into different frames, and 268 hotels from 109 cities. In pre-training, the generator the epoch range is 0 to 115. The test loss starts from 10.169 which can be accumulated as 1 then it decreases up to 115 epochs. The test loss is around 9.09 can be denoted as 0.9 according to 0 - 1 value. In the adversarial training, the training value starts from 9.085 after accumulates it become 0.985 as per turns. We used 200 epochs for the discriminator part, at last, we get the test loss as 8.77 and can be accumulated as 0.877 after the evaluation as per setting value from 0 to 1. These values are comparatively better than the baseline models for this work.

Table I shows the results of our proposed approach. We have shown the success rate and number of turns, also reward values have performed efficiently better than the previous techniques. The result of the new technique has compared with the previous techniques as shown.

TABLE. I. Performance of Agents

Agent names	Success rate of Agent	Number of Turns	Number of Rewards
Rule	.3210	46.21	-24.08
RL	.4432	45.30	-1.835
HRL	.6419	44.26	35.38
Cas-GAN	**.6625**	**43.10**	**35.70**

TABLE. II. Performance of Model Training

Agent	**Number of epochs for pre-training**	**Number of epochs for adversarial**	**Adversarial loss**	**Pre-training loss**
Seq-GAN	115	150	8.71	9.24
Cas-GAN	**115**	**200**	**8.67**	**9.08**
RL	115	150	9.45	10.17

Table II shows that the pre-training loss for the previous technique (SeqGAN) is more than our technique (Cas-GAN). The pre-training loss for 115 epochs is 9.21, and for adversarial training, it is 8.73. While for CasGANs pre-training loss is less than the previous technique (Seq-GAN) as 8.67 for 200 epochs and 9.08 for 115 pretraining epochs. While for the RL agent the pretraining loss is 10.17 and the adversarial loss is 9.45 is higher than our approach. It shows the model works more efficient when to train the dialogues and it gives more related information about the user query. The test loss is considered as the unmatched number of dialogues in a conversation.

VII. Conclusion

Recent research has suggested dialogue policies can be efficiently learned by using formalisms of reinforcement learning and Markov decision process. This work introduced a new approach to learn the dialogue policy for the efficiency of user-system responses. Cas-GANs is using the GANs network architecture and connecting to the GCN for generating the fake data by the generator network of GANs. The discriminator part successfully chooses the best rewards for the user query and sent it back to the generator for the next queries. The proposed technique is a new addition to GANs and it is comparable to the previous techniques HRL, Rule etc. To train the policy learning by decreasing the number of turns in the shape of dialogue terms shows that the model is working better and more efficiently trained by improving the policy-based RL techniques. In future, we can improve the modeling techniques for the improvement of dialogue policy learning, and can apply this proposed model to the other datasets.

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Prioritization of Software Functional Requirements: Spanning Tree based Approach

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***Abstract*—Requirements prioritization shows significant role during effective implementation of requirements. Prioritization of requirements is not easy process particularly when requirements are large in size. The current methods of prioritization face limitations as the current prioritization techniques for functional requirements rely on the responses of stakeholders instead of prioritizing requirements on the basis of internal dependencies of one requirement on other requirements. Moreover, there is need to classify requirements on the basis of their importance i.e. how much they are needed for other requirements or dependent on other requirements. Requirements are first represented with spanning trees and then prioritized. Suggested spanning tree based approach is evaluated on requirements of ODOO ERP. Requirements are assigned to four developers. Time estimation with and without prioritization are calculated. The difference in time estimation with prioritization and without prioritization shows the significance of prioritization of functional requirements.**

Keywords*—Requirements prioritization; functional requirements; spanning tree

I. Introduction

Requirement engineering is important and critical phase of software engineering which deals with how requirements should be collected from users in more discipline and systematic way [1][2][3]. The collected requirements should be properly managed before implementation and in this regard prioritization of requirements becomes more essential [4][5]. Requirements prioritization deals with assigning priority to requirements [6]. As software development becoming more complex in the recent years, prioritization have carried high significance in managing requirements successfully [7]. Elicitation and prioritization are two core activities of RE [8][9][10]. In a large software development projects such as an Enterprise Resource Planning (ERP), requirements are huge and prioritization process becomes much difficult [11]. When the stakeholder wishes to implement each and every requirement within a limited time and a limited budget, prioritization of the requirements become necessary [12][13][14]. As all types of requirements are inter-dependent with each other, there is critical need of collaboration among software developers and stakeholders during requirements prioritization especially when requirements [13]. Many techniques are suggested by authors to prioritize requirements, some techniques are suitable for prioritizing business requirements [15][16], some techniques are suitable for functional requirements and some techniques are suitable for nonfunctional requirements (NFRs) [17]. No such technique is either applied or suggested for functional requirements that can solve dependency issues of requirements in parallel developing large software systems for timely delivery. The objective of current research study is to propose an efficient approach of prioritizing software functional requirements from development perspective.

The remaining of this paper proceeds as follows. Section 2 presents background study conducted. Section 3 presents design of the research methodology. Section 4 discusses requirements prioritization. Section 5 presents case study conducted and finally Section 6 concludes with some indication for future work.

II. Background Study

AHP is the most common and applied technique identified from literature. AHP is scalable for small size requirements and face time complexity problems when size of requirements is large. As AHP pairwise compare each requirement against all other requirements so time complexity increases with increase size of requirements. Total number of comparisons with AHP is equal to n * (n-1)/2 e.g. if requirements are 10, then total comparisons will be 45. If total requirements are 20, total comparisons will become 190 and thus number of comparisons increases with increase size of the requirements [18][19].

Cumulative voting (CV) or 100 dollar is a technique [20][21] in which 100 dollars or points are given to the stakeholders and they have to assign these dollars or points to specific requirement. Requirements that are assigned more dollars will acquire high priority while those requirements that are assigned with less dollars will acquire low priority. Even though this technique is very simple in use, but it works better for small size requirements where determining the priorities of requirements is not tough and when size of requirements is too large, it becomes difficult to prioritize with voting method. This technique is user based technique because it is subjective to the inputs of users. Another big issue that can arise with this method is that stakeholders may assign dollars to some requirements that are not so important and may ignore some high priority requirements. Stakeholder can assign zero to some requirements. When the number of stakeholders are more than one, then distributing dollars on requirements may cause conflicts.

Using numerical assignment (NA) technique, requirements are categorized into high, medium and low priority groups and numerically assigned requirements to these groups. Inside each group, all requirements are considered to be same in priority [22].

Group discussions and decision are also helpful to prioritize requirements. After getting remarks from stakeholders or experts, group of experts will analyze the requirements in which each group member will score for that. At the end on the basis of group decision and score, all the requirements will be prioritized accordingly [23].

In another research study, requirement ranking function with graph is applied using binary search algorithm for comparing the customer feedback and thus priority and with original order of requirements in priority list is calculated. The main goal is to reduce the difference between true and estimated value of priority [24].

Assigning priority to NFRs is that much important as much of assigning priority to functional requirements. Using method similar to AHP, author has defined three steps for assigning priority to NFRs. 1) Based on pairwise comparison, assign values to different NFRs. 2) Based on functional requirements, assign priority values to NFRs. 3) Calculate priority by matrix multiplication. Well-organized prioritization of NFRs is presented [25].

Machine learning approach is presented during requirements elicitation phase in order to reduce the efforts during prioritization. Case-Based Ranking (CBR) is discussed which combines stakeholder preferences with requirements ordering approximations computed through machine learning approaches [6].

Using fuzzy logic and decision tree, the idea and detail evaluation of framework is presented which can examine various prioritization techniques. It is an intelligent approach for prioritizing newly upcoming requirements by getting inputs as parameters. On the basis of different parameters under different scenarios, this technique will decide that which technique is best under specified conditions. The condition can be type or size of requirements [26].

Although a lot of work is done to prioritize different types of requirements but still no work is done to prioritize requirements from developers perspective especially in parallel development where multiple team members work in parallel and assigning low priority to important requirements can delay whole project.

III. Design of Research Methodology

Fig. 1 shows the step by step approach of resign design.

Requirement elicitation process

Elicitation is the first phase for collecting user requirements for any software system. Various elicitation techniques such as background study, interview are applied to collect requirements from users. The quality of software product and its timely delivery depends on how well requirements are collected.

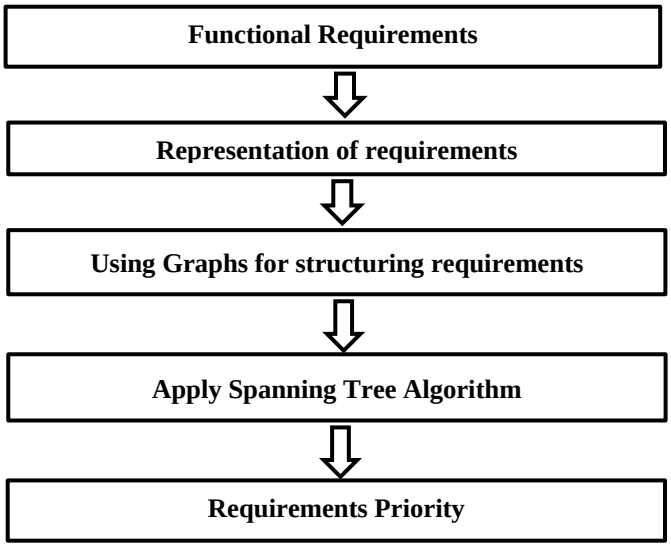

Fig. 1. Research Design Process.

A. Representation of Requirements

The collected requirements from users are represented with symbols e.g. R1, R2, R3, Rn. with surrounded round shape as shown in Fig. 2.

B. Using Directed Graph for Structuring Requirements

A graph is a pictorial diagram of a set of objects that are inter-related. The interrelated entities are characterized by points named as **vertices**, and the links that inter-relate the vertices are called **edges**.

- **Nodes** are typically represented by circles or ovals (though technically they can be any shape of your choosing). In this study requirements represents nodes i.e. R1, R2, R3 represent nodes of the graph.
- **Edges** are the connections or links between the nodes. An edge links two nodes. They are generally represented by lines, or lines with arrows.

Directed acyclic graph is a graph without having any cycles (a cycle is a complete circuit). When succeeding the graph from node to node, you will certainly not visit the same node twice. A directed acyclic graph is an acyclic graph that has a direction as well as an absence of cycles [27][28] [29]**.**

- **Vertices set** = {R1, R2, R3, R4, R5, R6, R7}.
- **Edge set** = {(R1, R2), (R1, R3), (R2, R4), (R2, R5), (R3, R6), (R4, R7), (R5, R7), (R6, R7)}.

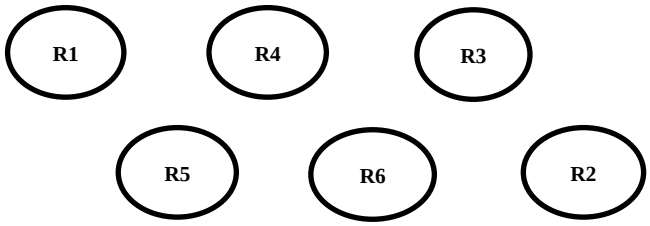

Fig. 2. Representation of Requirements using Specific Notations.

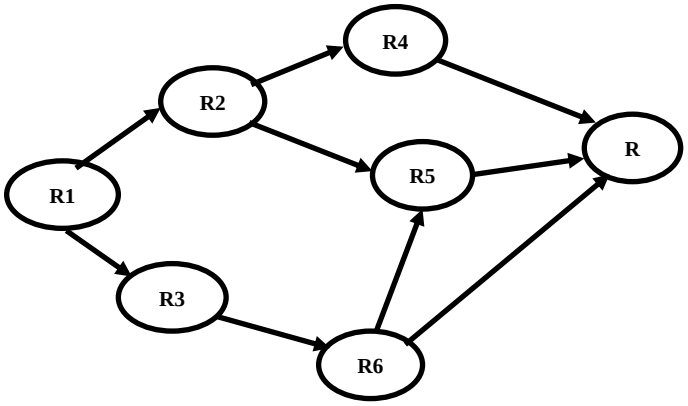

Fig. 3. Requirements Linked through Directed Acyclic Graphs.

Requirements inside directed graph can be either depended on other requirements or either needed for other requirements or can be both. Dependent requirements are those requirements that rely on other requirements for implementation and needed requirements are those on which other requirements are dependent. The requirement that points to some requirement is needed requirement while requirement on the arrow side is dependent. In Fig. 3, R1 is required for completion of R2 and R3, while R2 is required for the completion of R4, R5 and R3 is required for completion of R6. Similarly for the implementation of R5, R2 and R6 are needed. R4, R5 and R6 are needed for R7.

The reason for considering directed graphs instead of undirected is because undirected graphs points in both direction and it is not possible that a requirement is consider both depended as well as needed at the same time. During requirements implementation, cycles are not possible e.g. if there are three requirements such as R1, R2 and R3 as shown in Fig. 3. Consider if R2 is required for R1, R6 is required for R4 and R4 is again required for R2, R3 and R5 then cycle will create which means for R1 implementation, R2 should be implemented first but for R2, R4 should be implemented first.

C. Spanning Tree Formation

Spanning trees are special sub graphs of a graph that have several important properties. First, if T is a spanning tree of graph G, then T must span G, meaning T must contain every vertex in G. Second, T must be a sub graph of G. In other words, every edge that is in T must also appear in G. Third, if every edge in T also exists in G, then G is identical to T.

Spanning trees can be found in linear time by simply performing breadth-first search or depth-first search. These graph search algorithms are only dependent on the number of vertices in the graph, so they are quite fast.

There are a few general properties of spanning trees. Find all possible trees from graph. Starting point will be the requirement which is needed for other requirements such that the pre requisite requirements will come to the top (parent). The pre-requisite requirements will be the parent of all those requirements for which they are needed.

In below graph of Fig. 4, R2 is required for R1 but R1 is not required for other requirements so first tree will include only R1 and R2. Similarly R3 is also required for R1 and R4, R5 and R6 all are needed for R3, so from this point onwards three trees are possible. First will contain R4, R3, R1, second R5, R3, R1 and the third one with R6, R3, R1. As R6 is also needed for other requirements, so the child's of R6 will increase which will include R7 and R8. R8 is now needed for R9, so R9 will become child of R8 and further R9 is required for R10, R11 and R12 so all these will be the child's of R9. R11 is required for R13 and R14. R10 and R11 are child requirements of R9.

Thus by following either depth first searching (DFS) or breadth first searching (BFS) algorithm, the resulted spanning trees are shown in Fig. 5. With DFS, after the visit of R6, it can visit either of R3, R7 and R8, suppose it visit R3, and then it can't visit any of R7 and R8 before the child node of R3. After that it will visit R7, as it has no further child's, so it will go and visit R8 and then R9. Now using DFS, it can visit any of R10, R11 and R12. After visit of R10, it will visit R11 which is the child of R10. From R11, it will visit R13 and then R14. In last it will visit R12.

The same problem can be solved through BFS. Let's take example of tree 3. By applying BFS, it visits R6, then R3, R7 and R8 and then R1 and R9. After R9 visit, it visit R10, R12 and R11 and at the end it will visit R13 and R14.

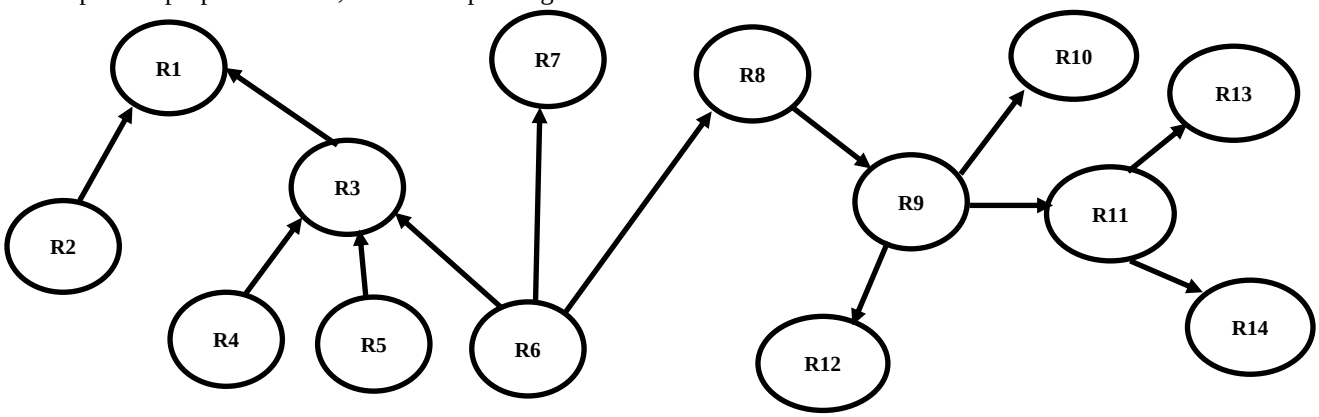

Fig. 4. Graph Connecting Requirements for Making Spanning Tree from Graphs.

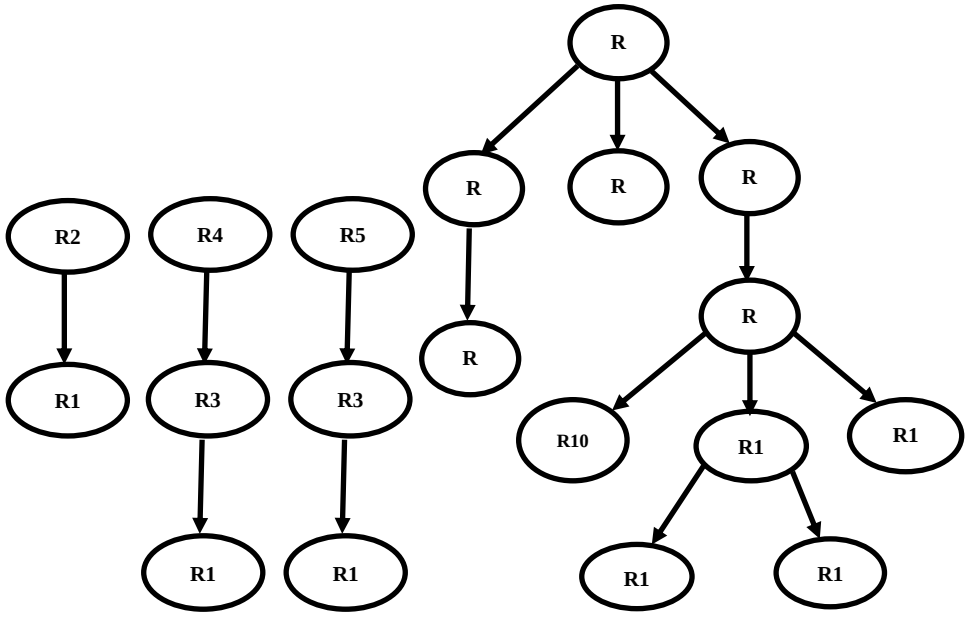

Fig. 5. Tree 1, Tree 2, Tree 3, Tree 4 Respectively.

IV. Requirements Prioritization

In Fig. 5, priority of pre-requisite requirements will be greater than priority of requirements for which they are needed e.g. R4 priority will be greater than R3 while R3 priority will be greater than R1. In R4 and R6, priority of R6 should be greater because it is needed for greater number of requirements. In this case, R6 is although needed for three requirements R3, R7 and R8 but these requirements are further needed for other requirements. So requirement priority will be calculated from its overall need either directly or not. Similarly dependency of requirement in spanning tree will reduce its priority, e.g. priority of R13 and R14 will be lower than priority of R10 and R12 because R10 and R12 are dependent on three while R13 and R14 are dependent on four requirements.

Requirements prioritization has a significant role in successful implementation of software projects. Quality and success of any software projects is not only associated with how much software meets its functional requirements but it is also associated with timely delivery of software projects. Timely delivery of any project can be assured when time estimation of whole project is correct and along with it requirements waiting time for other requirements is minimum.

Requirements of parallel team developers can be inter-related and this can increase the waiting time of requirements if pre-requisite requirements are not available in time.

Requirements need for other requirements can easily be calculated by counting number of child nodes and similarly requirements dependency on other requirements can be calculated by counting number of parent nodes of requirement in tree. E.g. in tree 04 of Fig. 5, the parent nodes of R9 are two and child nodes are total five. In this case, although child nodes of R9 are three but R11 further has two more child nodes, so in this way total child become five for R9. In similar way, parent node of R9 is R8 and parent of R8 is R6, so in this way, total requirements on which R9 is dependent are two. Now question arise what will be the net priority of R9 in this case because only from child nodes, the priority of requirements can't be determined because if we ignore dependent requirements than results can be biased e.g. if there are two requirements and both are needed for same number of other requirements but dependency of these requirements on other requirements is different, then requirement that is less dependent on other requirements will get higher priority. From the difference of child nodes and parent nodes values, net priority of requirement can be calculated. The net priority of R9 will be equal to 3 in this way. Similarly priority of R3 will be equal to 2 because parent nodes of R3 are three and child nodes are one, the difference will equal to 2.

Now if child nodes of requirements such as R1 are zero and parent nodes are more than zero. In such case priority will be in negative. E.g. here the priority of R7 will be equal to -1. Priority of independent requirements will be 0 and thus requirements with negative priority will be given low priority as compare to requirements with 0 priority. Priority of R1 will equal to -5. For R1, parent R3 is repeated in three trees, but it will be counted as 1.

Negative or zero priority of requirements can be adjusted by adding positive same number with all requirements. E.g. To adjusted priority of R1 from -5 to 1, value 6 can be added to this. Thus value 6 will be added with all requirements in similar way. Net priority of R3 will be equal to 8. Requirements order with adjusted and without adjustment of priorities will be same.

V. Case Study

The suggested approach is evaluated on requirements ODOO open source ERP system. It consist of ninety six (96) high level functional requirements. The prioritization algorithm is applied to these high level functional requirements only. The detail is given below in Table I.

TABLE. I. REQUIREMENTS DETAIL OF ODOO ERP

Requirements	Required for	Requirements	Required for	Requirements	Required for
R1 (Employee)	R2,R4,R10, R11,R12, R17,R18, R20, R21, R22, R23, R25, R67, R81,	R33 (customer detail)	R24, R35, R36, R39,R55, R61, R64, R73, R90, R55	R65 (supplier ledgers)	
R2 (Public information's of employee)		R34 (products detail)	R35, R42, R60, R66,R70,R71, R91, R61	R66 (stock ledgers)	
R3 (Employee personal info)		R35 (sale)	R32, R51, R61, R62,	R67 (HR expense management)	
R4 (Contact info)		R36 (customer refund)		R68 (purchase return view)	
R5 (Job position)		R37 (Sales persons)	R35, R36, R58, R63,	R69 (sale return view)	
R6 (Department)	R5, R81, R67	R38 (customer receipts)		R70 (Transfer In)	
R7 (Job information's)		R39 (customer payment)	R38, R55	R71 (Transfer out)	
R8 (Manager)	R5, R24, R67	R40 (supplier receipts)		R72 (order to suppliers)	
R9 (Coach)		R41 (supplier detail)	R42, R44, R52, R60, R65, R72	R73 (order from customer)	
R10 (Contract information's)		R42 (purchase)	R51, R59	R74 ()	
R11 (Contract reference information's)		R43 (Sales man)	R42, R44	R75 (Balance sheet)	
R12 (Salary generation)	R21,	R44 (supplier refund)		R76 (compose message)	R79
R13 (Salary rules)		R45 (supplier payment)	R40,	R77 (message inbox)	R80
R14 (Salary structure)	R12	R46 (bank statement)	R47	R78 (message Draft)	
R15 (Salary categories)	R12	R47 (bank detail)	R49, R50, R53	R79 (sent messages)	
R16 (Registers)	R12, R13,	R48 (cash registers)		R80 (message Searching)	
R17 (Apply for leave)	R19,R20,	R49 (put money in)		R81 (Job position in recruitment)	
R18 (Allocation request)		R50 (put money out)		R82 (Job)	
R19 (Approval)		R51 (Profit and lost)		R83 (appraisal form)	
R20 (Leave summary)		R52 (supplier payment)		R84 (create a job position)	
R21 (HR payroll)		R53 (Journals accounts)	R54	R85 (Recruitment form)	
R22 (HR Expenses)		R54 (Chart of accounts)		R86 (Job selection process)	
R23 (HR expenses)		R55 (Analytic accounts)	R54	R87 (Link tracker)	
R24 (Project management)	R26, R27, R28, R29	R56 (company)		R88 (Mass mailing)	
R25 (Add team members)		R57 (region)	R58	R89 (contacts)	
R26 (Extra information's)		R58 (Area)		R90 (business pipeline)	
R27 (Project stages)		R59 (purchase view)		R91 (manufacturing orders)	
R28 (View current task)		R60 (purchase return)	R68,	R92 (fleet management)	R93,
R29 (create a task)	R31,	R61 (sale return)	R69	R93 (Vehicle repairing)	
R30 (Extra information's)		R62 (sale view)		R94 (Directories for documents)	R96
R31 (Tasks stages)		R63 (salesman ledgers)		R95 (Documents history)	R96
R32 (customer invoice)	R36	R64 (customer ledgers)		R96 (Documents attachments)	

From the information's of Table I, directed graph can be easily drawn and can identify all possible number of spanning trees. Table II shows the resulted 18 spanning trees from requirements of ODOO ERP. Requirements are further categorized into groups on the basis of common requirements.

By applying prioritization algorithm as explained above, requirements of ODOO ERP are prioritized accordingly as shown in Table III.

Calculated priorities of requirements as a result of apply prioritization technique using spanning tree are shown in Table III. Priorities are then adjusted such that minimum priority is 1. An experiment was conducted on parallel developing software requirements of ODOO using priority values from Table III. Requirements of software are distributed in four developers i.e. A, B, C and D as shown in Table V in such that there exists dependency between requirements of developers. Before applying prioritization algorithm, efforts in hours needed to implement all these individual requirements are calculated using USE CASE POINT estimation technique as shown in Table IV. Difference of total estimation time of these developers and overall project before and after prioritization will show significance of spanning tree based prioritization approach.

Requirements are distributed in such way that requirements of C and D are dependent on A while requirements of B are totally independent as shown in Table V.

Case 1: In this case, all requirements of A, B, C and D are arranged in ascending order of priorities i.e. requirements are not prioritized (except pre-requisite requirements that should be implemented first) as shown in Table V.

Case 2: In this case, all requirements of A, B, C and D of Table V are prioritized in descending order of priorities such that requirements of every team member are fully prioritized.

Time estimation based on sum of time estimation of all requirements for each developer in both cases is shown in Table VI.

Total estimation time of the project depends on the maximum time completion of any developers. From Fig. 6, for case 01, maximum time taken by developer D is 1750 hours and for case 02, maximum time taken by developer C is 940 hours. The delay or exceed in time estimation is case 01 is due to waiting time of requirements for their pre-requisites while after prioritization, delway is reduced due to reduction in waiting time for requirements.

TABLE. II. RESULTED SPANNING TREES

Tree	Root	Requirements
T1	R1	R81, R23, R25, R2, R4, R10, R11, R12, R17, R18, R19, R20, R22, R21, R67
T2	R6	R5, R67, R81,
T3	R8	R5, R67, R24, R26, R27, R28, R29, R31
T4	R14	R21
T5	R15	R21
T6	R16	R12, R13, R21
T7	R46	R47, R49, R50, R53, R54
T8	R57	R58
T9	R37	R58, R63, R35, R61, R62, R32, R36, R69
T10	R33	R73, R55, R54, R35, R61, R62, R32, R36, R69, R64, R38, R39,
T11	R34	R42, R51, R59, R60, R66, R68, R70, R71, R80, R90, R35, R61, R62, R32, R36, R69
T12	R43	R42, R51, R59, R44
T13	R41	R42, R51, R59, R44, R52, R60, R68
T14	R92	R93
T15	R45	R40
T16	R76	R79
T17	R95	R96
T18	R94	R96

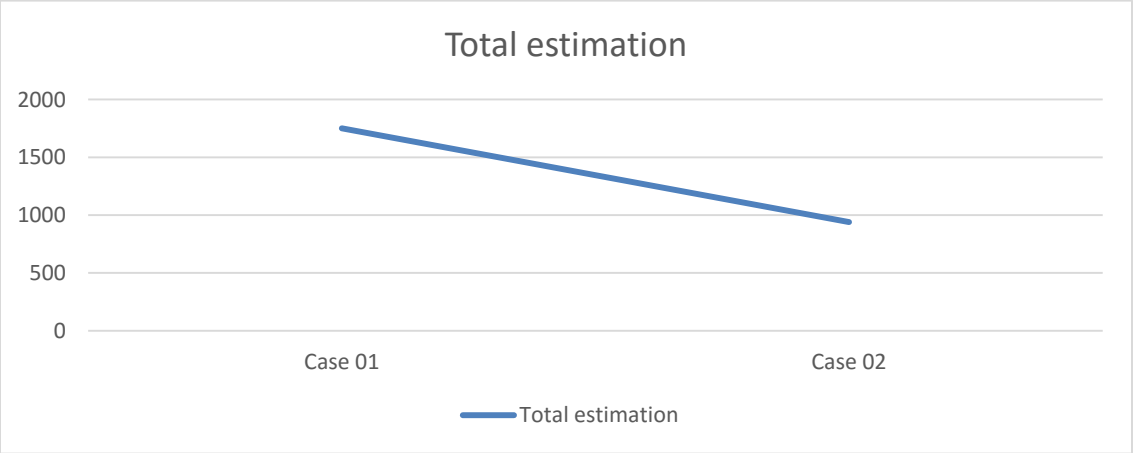

Fig. 6. Total Estimation Time of Requirements for Case 01 and Case 02.

TABLE. III. PRIORITY AND IMPORTANCE VALUES ASSIGNED ON THE BASIS OF CHILD NODES

Requirement	Total child's/priority	Adjusted priority	Requirement	Total child's/priority	Adjusted priority
R1	24	30	R49	-2	4
R2	-1	5	R50	-2	4
R3	0	6	R51	-2	4
R4	-1	5	R52	-1	5
R5	-1	5	R53	-1	5
R6	3	9	R54	-3	3
R7	0	6	R55	-1	5
R8	8	14	R56	0	6
R9	0	6	R57	1	7
R10	-1	5	R58	-1	5
R11	-1	5	R59	-5	1
R12	0	6	R60	0	6
R13	0	6	R61	-3	3
R14	0	6	R62	-4	2
R15	0	6	R63	-1	5
R16	0	6	R64	-1	5
R17	1	7	R65	-1	5
R18	-1	5	R66	-1	5
R19	0	6	R67	-1	5
R20	-2	4	R68	-2	4
R21	-3	3	R69	-5	1
R22	-1	5	R70	0	6
R23	-1	5	R71	-1	5
R24	4	10	R72	-1	5
R25	-1	5	R73	-1	5
R26	-2	4	R74	0	6
R27	-2	4	R75	0	6
R28	-2	4	R76	1	7
R29	-1	5	R77	0	6
R30	0	6	R78	0	6
R31	0	6	R79	-1	5
R32	-3	3	R80	-2	4
R33	13	19	R81	-1	5
R34	16	22	R82	0	6
R35	3	9	R83	0	6
R36	-5	1	R84	0	6
R37	8	14	R85	0	6
R38	-2	4	R86	0	6
R39	2	8	R87	0	6
R40	-1	5	R88	0	6
R41	9	15	R89	0	6
R42	1	7	R90	-1	5
R43	4	10	R91	0	6
R44	-1	5	R92	1	7
R45	1	7	R93	-1	5
R46	5	11	R94	1	7
R47	4	10	R95	0	6
R48	0	6	R96	-1	5

TABLE. IV. TIME ESTIMATION FOR EACH REQUIREMENT

Requirement	Efforts/hours	Requirement	Efforts/hours	Requirement	Efforts/hours	Requirement	Efforts/hours
R1	20	R25	20	R49	30	R73	30
R2	20	R26	20	R50	30	R74	30
R3	20	R27	20	R51	30	R75	30
R4	20	R28	20	R52	30	R76	30
R5	20	R29	20	R53	30	R77	20
R6	20	R30	20	R54	30	R78	20
R7	20	R31	20	R55	30	R79	30
R8	20	R32	30	R56	20	R80	30
R9	20	R33	20	R57	20	R81	30
R10	20	R34	20	R58	20	R82	20
R11	20	R35	60	R59	30	R83	30
R12	20	R36	60	R60	60	R84	30
R13	20	R37	20	R61	60	R85	20
R14	20	R38	30	R62	30	R86	30
R15	20	R39	30	R63	30	R87	20
R16	20	R40	30	R64	30	R88	20
R17	30	R41	20	R65	30	R89	20
R18	30	R42	60	R66	30	R90	30
R19	30	R43	20	R67	30	R91	30
R20	20	R44	30	R68	30	R92	30
R21	60	R45	30	R69	30	R93	20
R22	30	R46	20	R70	30	R94	30
R23	30	R47	20	R71	30	R95	20
R24	20	R48	20	R72	30	R96	20

TABLE. V. REQUIREMENTS DISTRIBUTION IN FOUR DEVELOPERS (CASE 01)

A	B	C	D
Requirement	Requirement	Requirement	Requirement
R79	R1	R63	R51
R31	R21	R64	R71
R27	R19	R73	R90
R26	R25	R66	R70
R28	R11	R45	R80
R58	R10	R40	R55
R29	R4	R75	R74
R5	R2	R39	R91
R67	R23	R38	R48
R81	R22	R43	R82
R30	R20	R44	R83
R77	R18	R41	R88
R78	R13	R65	R89
R56	R12	R72	R86
R6	R17	R60	R87
R24	R15	R68	R84
R57	R14	R52	R85
R76	R3	R42	R95
R37	R7	R59	R94
R8	R9	R35	R96
R33	R16	R61	R92
R34		R32	R93
		R69	R46
		R36	R47
		R62	R49
			R50
			R53
			R54

TABLE. VI. TIME ESTIMATION OF EACH DEVELOPERS RESPECTIVELY

A		**B**		**C**		**D**	
Case 01	Case 02	Case 01	Case 02	Case 01	Case 02	Case 01	Case 02
470 hours	470 hours	520 hours	520 hours	1320 hours	940 hours	1750 hours	730 hours

VI. CONCLUSION

In this research work, functional requirements of software are prioritized from developer's perspective using spanning trees. Functional requirements are inter-related with directed graph and were converted to spanning trees. Based on prioritization technique using spanning trees, requirements of ODOO ERP are prioritized accordingly. Prioritized requirements reduce inter-dependency issues and delays and thus assure timely delivery of projects. An experiment was conducted with four developers and requirements were distributed such that there exist dependency in requirements of different developers. Time estimation of each requirement was calculated using use case point estimation technique. Total estimation time of each developer was calculated for both prioritized and un-prioritized requirements. There found a significant difference in total estimation time in both cases which shows the importance of prioritization and its effect on overall estimation time. In future work, spanning concept will be used to distribute functional requirements in more efficient way on parallel distributing team members.

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A Behavioral Study of Task Scheduling Algorithms in Cloud Computing

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***Abstract*—All the services offered by cloud computing are bundled into one service know as IT as a Service (ITaaS). The user's processes are executed using these services. The scheduling techniques used in the cloud computing environment execute the tasks at different datacenters considering the needs of the consumers. As the requirements vary from one to one, and so the priorities also change. The jobs are executed either in a preemptive or non-preemptive way. The tasks in cloud computing also migrate from one datacenter to another considering load balancing. This research mainly focused on the study of how the Round Robin (RR) and Throttled (TR) scheduling techniques function subject to different tasks given for processing. An analysis is carried out to measure the performance based on the metrics like response time and service time at different userbases and data centers. The consumers have the option to select the server broker policy as they are the ultimate users and payers.**

Keywords*—Cloud computing; load balancing; service broker policy; scheduling

I. INTRODUCTION

Distributed computing innovation has risen as another data innovation framework for the quick creating IT industry. In distributed computing, data is for all time put away in vast scale server farms on the Internet everywhere throughout the world. And is available to the customers, furthermore, including desktops and convenient PCs, sensors, and so forth. With the "cloud" as an allegory for the internet [1], distributed computing guarantees to convey exceedingly adaptable IT-empowered information, programming, and equipment capacities as support of outside customers with the internet.

Furthermore, the profoundly versatile calculation capacity of the cloud server farms can additionally help and quicken most computation intensive administrations and works viable. Distributed computing is imagined as the key innovation to accomplish economies of scale and in the arrangement and operation of IT. Various types of data are stored in the form of text, voice, images, videos; and through the internet, they access from any corner of the world. Moreover, the way how they are stored and are available is not the concern of the user and is all taken care of by the IT administrators through an interface with Cloud Computing. In combination, it can be called as "IT as a Service," or ITaaS [2], packaged to the end clients as a virtual server farm as shown below in Fig. 1. The cloud administrators are responsible for managing the relationship between the client and the service provider based on Service level agreement (SLA) [3]. Based on the various services provided by the service providers, they also monitor the performance. With Software as a Service (SaaS), they ensure that customer satisfaction is guaranteed. Platform as a Service (PaaS) provides and supports the implementation of processes with provisioning, testing, and deployments. Infrastructure as a Service (IaaS) helps in operational management and control over the resources provided for the service. The collaboration between the PaaS and IaaS helps to reduce the IT capital expenditure and operating expenditure by providing virtual infrastructure, security requirements, and other essential requirements.

As to signs of progress in portable correspondence innovations, it is triggering another flood of the client request for prosperous, versatile administration. Versatile clients dependably expect broadband Internet get to wherever they go, communicate with each other employing informal organizations while moving; besides, they are looking for omnipresent access to an abundance of media-based substance and administrations. Since cell phones are resource limited naturally, it is necessary for the cloud to give computational help to numerous media-rich applications with authentication [4]. The mix of versatile media and distributed computing very emerges various specialized difficulties, and the central pressure between asset hungry interactive media streams and power-constrained cell phones exists. The exertion for giving a general rich-media encounter over any screen is ordinarily ruined by the heterogeneity among consistently developing cell phones, as showed in their unique physical shape factors, middleware stages, and natural capacities. Besides the improvements of creative inescapable portable administrations, e.g., versatile video spilling, rich media spread, observation, gaming, e-social insurance, and so on, can be enormously encouraged by versatile distributed computing stages utilizing rose and rising advances.

Cloud stages are empowering new, elaborate plans of action and organizing more internationally based incorporation arranges in coming years than numerous investigator and admonitory firms anticipated. Joined with cloud services appropriation expanding in the mid-level and little and medium organizations, driving specialist, including Forrester, are changing their gauges upward. The various cloud service models listed in Table I, shows the services they offer along with the type of flexibility with examples.

According to the prediction by IDC, as shown in Fig. 2, the need for public cloud is going to increase each year, and hence, the tasks scheduled at each data center needs to be managed. The functions in the cloud are to process the user's requirements like providing a platform, infrastructure, or

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software as a service. Also, being simple to use, most of the customers are moving their tasks to the cloud. The payment for the use is made based on the policy pay-as-you-use. So, there is no chance of being charged more for not using the service.

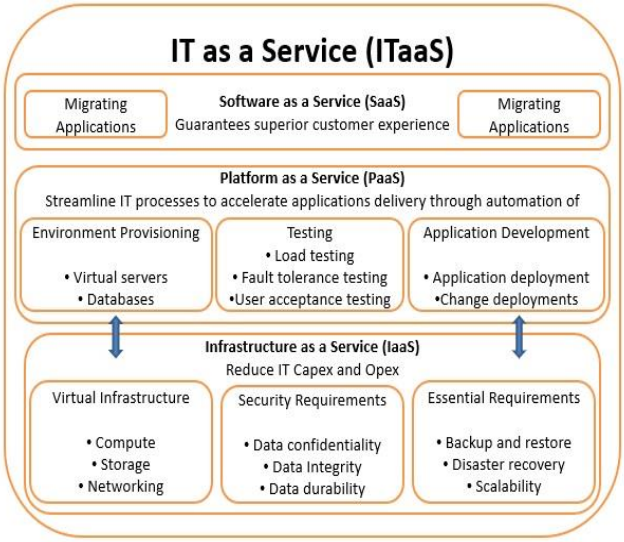

Fig. 1. IT as a Service (ITaaS).

TABLE. I. CLOUD SERVICE MODELS, SERVICES, EXAMPLES [5]

Cloud Service Model	Services	Frequency	Examples
IaaS	Compute, storage, and network service	High	Amazon Elastic Compute Cloud (EC2), Defense Information Systems Agency's DISA milCloud, Google Compute Engine, Microsoft Azure
PaaS	Application program interfaces (API) and services	Medium	Amazon Elastic MapReduce, MathWorks Cloud, Red Hat OpenShift
SaaS	Full-fledged applications	Low	Google Gmail, Microsoft Office 365, Facebook

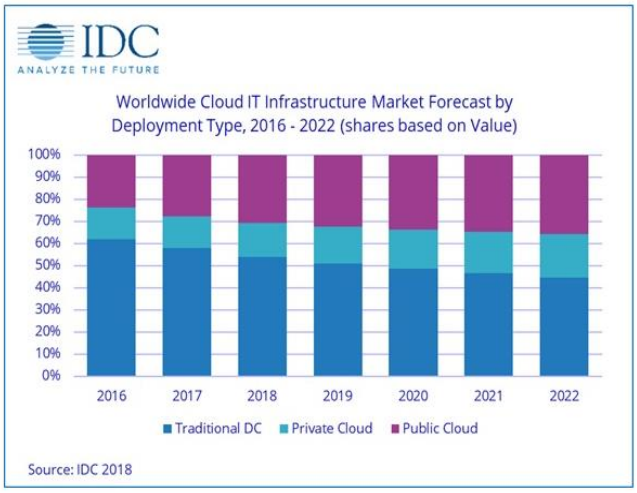

Fig. 2. Worldwide Cloud IT Infrastructure Market Forecast[6].

The data centers located in remote places are responsible for providing the necessary service. The resources are allotted to the processes at the data center using the policy to complete the tasks efficiently. The performance of different task scheduling algorithms varies based on the policy.

In this study, the researcher plans to study the various task scheduling algorithms in cloud computing and analyze the behavior of those scheduling algorithms subject to different requirements of the users. The mentioned study shows the effects and impact of different scheduling algorithms, which allows the user to decide on choosing a specific scheduling algorithm with a better QoS [7]. This research focuses on the study of the performance of various task scheduling algorithms in the cloud, considering the service broker policies. The metric used to measure the performance of each of the task scheduling algorithm is response time. The following questions are to be addressed to do so.

1) What are the characteristics of different task scheduling techniques?

2) Match the user requirements with the task scheduling technique.

3) Analysis of these scheduling techniques to have better throughput and less waiting time based on the service broker policy chosen.

The researcher concentrates on the standard scheduling algorithms used in cloud computing. However, these algorithms can be customized and modified with the changing requirements. This study will be a considerable contribution in the area of Cloud Computing to select the scheduling policy from the available different scheduling policies while meeting the needs of the users. It shows the researchers how the processing, storage, platforms, software are provided to the user by optimizing the response time and minimizing the waiting time. This study can help other researchers to enhance different scheduling algorithms based on their behavior to improve the QoS. It can also be used by the enterprises to decide on choosing the appropriate service broker policy matching their requirements to utilize the services offered by the cloud service providers.

The following is the conceptual framework for this research. The study of the effective strategy of different scheduling algorithms to process the tasks is studied. There are various ways how the scheduling algorithms behave when they execute at the nearest data centers, and when they migrate to the datacenters without the consent of the user. A study of different scheduling algorithms helps in knowing the behavior of such algorithms in this research. Comparative outputs between Round-Robin and throttled policies subject to separate service broker policy selected. Therefore, it helps to choose for the specific scheduling algorithm taking into consideration the requirements of the users to have a safe and secure transaction.

The organization of the rest of the paper is as follows. Section 2 presents a literature review, with the methodology used to analyze the results provided in Section 3. Section 4 contains discussion on analysis of results, Section 5 contains a conclusion, and finally, Section 6 presents future work directions of the study.

II. Literature Review

This section reviews the works done by different researchers in the area of cloud computing from the perspective of balancing the load. The authors in [8] have conducted a study on the load balancing algorithms. They implemented load balancing in cloud computing using checkpoints. Ranks are calculated by considering the requirements from the user and keeping the objective to maintain QoS so that the customers know on which cloud services can be selected.

The smart devices which are now prevailing much are also used to access the services of the cloud. The method of quickly obtaining cloud computing applications with rapid and fast-moving communication media is known as mobile cloud computing [9]. It examines on reducing the energy consumption by dynamically scheduling the tasks and proposes an algorithm considering the time, voltage, and processor constraints of the cyber-physical system. Further, in [10], the authors have shown how HTML5 is used to implement the applications and services of the cloud efficiently. Still, it shows the gaps between traditional cloud computing and mobile cloud computing.

From the systematic review conducted in [11], it shows very clearly how the resources will be allocated. In the process of resource management, though there are some challenges about resources like allocation, adaption, brokering, discovery, mapping, modeling, provisioning, scheduling, the distribution of resource to a task is critical. The parameters like throughput, time, response time, speed, availability, and so forth, were used to compare different policies. The study also addresses the problems of green computing by minimizing energy consumption.

The authors in [12] have presented a scheduling strategy based on genetic algorithm for task scheduling considering energy requirements as it is given more considerable attention than before. The results showed that it achieved the best solution with least or no migration. While in real cloud computing where there are dynamic changes in the virtual machines and the computing cost increases with the unpredicted load, it is concluded that the cloud data center always has an optimal energy-efficiency ratio and it can be obtained by efficient resource allocation.

In [13], the authors have proposed a load balancing algorithm named Firefly algorithm with neighborhood attraction (NaFA), where the tasks are allocated to such a virtual machine which is richly equipped with the resources and simulates from the social behavior of the fireflies. Just as the brighter one leads the other fireflies; many are attracted in the population. As more tasks are allocated to the same virtual machine, the time complexity is high. The balancing of the load at all the virtual machines is paid less attention.

To allocate the virtual machines online in a distributed cloud environment, the cloud service provider allocates the resources without the knowledge of considering the tasks are joining the pool in the future. The authors in [14] proposed algorithms that serve the functions present on different cloud architectures. While with the new emerging virtualized applications which are geographically distributed the complexity still increases if the data centers are increased.

In [15], the authors focused on minimizing the total weighted job response time. To reduce the job response time, they proposed a model wherein which the jobs generated from the users are deployed to the servers with upload and download delays. They have used OnDisc by setting the weight for each job based on job latency. The results showed that the total response time is reduced when compared with the heuristic algorithms.

The authors in [16] considered the dynamic resizing of virtual machines, as the size of the virtual machines shrink and expand when the resources are added and removed from the pool. This feature of cloud computing affects the performance as the cloud infrastructure functions in prescribed limits because of the scarcity of resource availability. The adverse effects of the tasks which are scheduled at one virtual machine have to be migrated to another as the resource is not available due to its elasticity feature were to be paid much importance.

Cloud computing in coordination with the Internet of Things (IoT) has put forth many challenges to be addressed. In connection with building the smart homes, a framework needed to bind the applications and implementations of such with the gaps to enable such implementations were discussed in [17]. The authors integrated the technologies like IoT and cloud to have an efficient cloud-centric IoT based solution as the information.

An online auction-based mechanism was proposed in [18] to allocate the resources to the users by the cloud service providers. The users intended to utilize the resources like processor, memory, storage which are nothing, but the virtual machines are allocated based on the quoted price by the users. Moreover, the cloud service providers cite their services, which can be provided to the users matching the incentives. This policy is utilized when all the tasks are stable, but for dynamic works, the online auction mechanism fails.

In [19], the authors considered different criteria to allocate the task to a particular datacenter. The resources at the data center are assigned to the tasks to complete the execution. Resources being the costliest components are to be effectively utilized without overloading them with the tasks and without keeping them idle too. The authors used à CloudSim simulator and simulated the results to show that their proposed algorithm performed better over the existing one in terms of throughput. However, they did not pay much attention to other criteria to measure the efficiency of the algorithm.

Migration of the tasks from one virtual machine (VM) to another is a part of balancing the load at the data centers. The authors in [20] introduced collaborative agents to migrate the tasks considering various requirements like hardware diversity, dynamic user requirements, wearable resources, imbalanced load, and energy usage. These agents proved to be efficient in performing the intended tasks while they did not consider a significant constraint of trust.

The authors in [21] considered the bandwidth requirements for task scheduling in cloud computing. They have proposed a decentralized belief propagation-based method where the agents and the tasks continuously change. Also, the authors made a comparison of the proposed plan with two other methods prevailing in task scheduling. The proposed way out ruled the different techniques in terms of shorter problem-

solving time and lesser communication requirements. While the focus was on task allocation, by decomposing the network, the security issues with such were also to be considered.

A balanced scheduler [22] is used to balance the tasks by the cloud service provider and the applications. The authors proposed a Balanced and file Reuse-Replication Scheduling (BaRRS) by using the replication and data reuse techniques where a task is split into subtasks and was run parallel to improve the system utilization but the fact that if one subtask delays then the complete job will also be delayed has been overlooked. However, the results showed that it performs well in optimistic situations.

From all the above review, it is evident that though the priority is to balance the load to attain a better throughput, it lacks an essential point on guiding the customer to choose a policy at the time of signing the service level agreement (SLA).

III. Methodology

The main aim of this research is to study the behavior of the scheduling algorithms, which can be either preemptive or non-preemptive [23] subject to the user requirements and the geographic location of the data center. The study aims to consider the number of virtual machines accessing with the user requirements like either to select the closest data center or to optimize the response time or to reconfigure dynamically with load balancing.

The study addresses the following questions:

1) What are the various user requirements?

2) What are the various scheduling algorithms available to have better throughput?

3) After knowing the requirements and the scheduling algorithms, which scheduling algorithm has to be chosen to match the user requirements and can a generalized framework be proposed for better performance?

The study mainly uses the following load balancing policies:

- Round Robin (RR)
- Throttled

Factors considered are as follows:

- Response time
- Data Center request service time

The researcher adopted an analytical research methodology in conducting the study. Open source available cloud simulation software called à CloudSim is used to get the results. The various load balancing algorithms have their methods to execute the tasks at different data centers. The results of these algorithms are used to analyze the performance and propose a framework for the consumers to adopt a respective policy if the option of selection is given to them in SLA[24]. Both the algorithms are measured in terms of response time and other metrics too and put forth the opportunity to the consumer to select based on the requirements and the amount they bid.

The response time can be defined as the time from which the request has arrived at the data center to the time at which the request starts processing. Data center request service time is defined as the time from which the request comes at the data center to the time the request completes processing.

The research is organized as:

- Study the various load balancing algorithms.
- Analyze the performance of the algorithms mentioned earlier in terms of metrics

Propose a solution by analyzing all the conditions for the consumers as they go with the policy of pay-as-you-use for the services they are using. It will help them to select an appropriate one considering the complexity of the task to be allocated to the datacenter.

IV. Analysis and Results

The simulator à CloudSim models and simulates various services offered by cloud computing, and it is an open source tool, which is widely used in academics and research. This tool allows the researchers to simulate the algorithms developed to meet the requirements of the users. From the various offered cloud computing services, Infrastructure as a Service (IaaS), is one of them, where the location of the data centers, servers, and the clients are widely scattered on a broad geographical area but still, there is uninterrupted service. The availability of the resources is a significant concern for any of the cloud service provider to serve the users without deadlock [25]. From the study of different algorithms implemented in à CloudSim, namely Round Robin (RR), Equally spread Execution load (EE), Throttled (TR), it is observed that these are used in two different types of scheduling like preemptive and non-preemptive scheduling. Preemptive scheduling is a type of schedule where the resources are allocated to the task either for a quantum of time or based on priority. While non-preemptive scheduling is adopted in a static environment where the resources of the task are determined initially so that the available resources are equally given to all the tasks based on the size and need.

The design of à CloudSim simulator covers the whole globe and is divided into five regions, with each region establishing the data centers and as many as user bases to be added manually providing an excellent graphical user interface to the users to configure the network.

Each region has its specified boundaries, and, in each area, there can be datacenters and the userbases. The user can configure the simulation, define the internet characteristics, and when everything is fixed, can run the simulation. So first, the data center is set to add many userbases by selecting the service broker policy. There are three types of service broker policies as closest datacenter, optimal response time, and reconfigure dynamically with the load which is to be attached to the application and is deployed at that data center.

In the main configuration after all the entities are set, then such an arrangement can be saved to perform the simulation. Once the datacenters and userbases with the server broker policy are set later, the advanced option to select the load

balancing system to be used in the data center is to be decided. By using the advanced option, the user tags the load balancing policy. If the tasks are to be executed in a preemptive environment, then RR and TR are to be used. However, the task to be implemented in a non-preemptive climate uses EE policy. Once the network is configured with the datacenters and userbases by selecting the policy to use as the closest data center for the service policy, Round Robin for the load balancing and then the simulator is run to get the results. The obtained results are summarized as follows.

The data centers are located in different regions like Region-0, Region-2, Region-5, while the userbases are found in regions 1, 3, 4, respectively. As the closest data center service policy is selected, it is observed that the data center (DC3) have no user bases allocated, and it is idle. So, the problem with such a policy is that there is no efficient use of resources and sometimes the nearest datacenters might be overloaded with the tasks to complete thereby increasing the response time and also the delay time. In addition to all these, the concern is to serve all the requests maintaining the QoS and avoiding the deadlock states. Sometimes some tasks might also migrate from one data center to another when such is overloaded. So, a list of all such tasks is to be considered for scheduling either before the resources are allocated or at the time of execution too.

Fig. 3 and Fig. 4 are the graphs derived by plotting the response times of different user bases using the RR policy and Throttled policy for three different types of service broker policies namely Closest datacenter, Optimal response time and reconfigure dynamically with loading respectively. The results show that, the response time for the userbase3 is very low as the load is considered dynamically, and the tasks are executed. As both UB2 and UB3 are assigned to DC2, it may result in high response time for UB3 so, according to re-configure dynamically policy, during runtime, the tasks at UB3 get shifted to DC3 and the response time is very less when compared with others.

Fig. 5 and Fig. 6 are the graphs derived by plotting the service times of different data centers using the RR policy and Throttled policy for three different types of service broker policies namely Closest datacenter, Optimal response time and reconfigure dynamically with loading respectively. The results show that the service time at the DC3 is more when compared with all the other data centers. It is because the load is considered here, and the network is reconfigured accordingly.

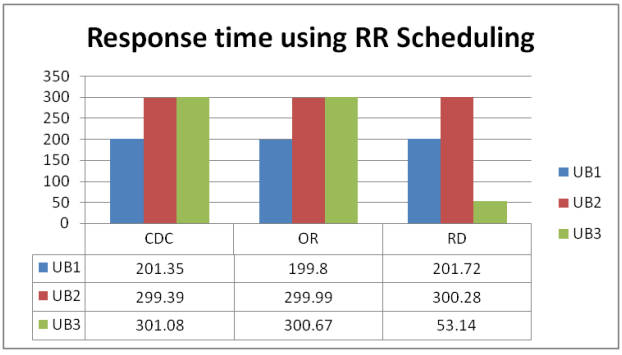

Fig. 3. Response Times of different user bases using RR Policy.

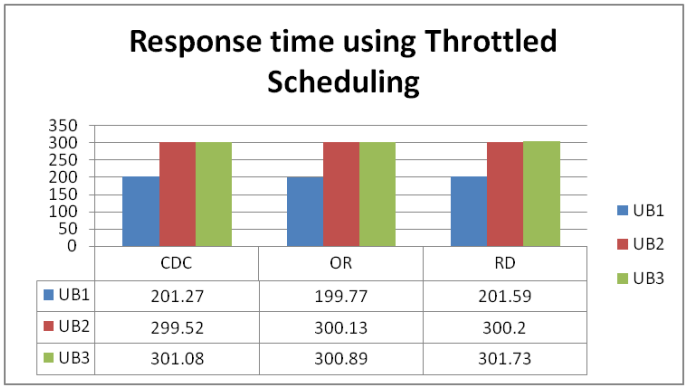

Fig. 4. Response Times of different user bases using Throttled Policy.

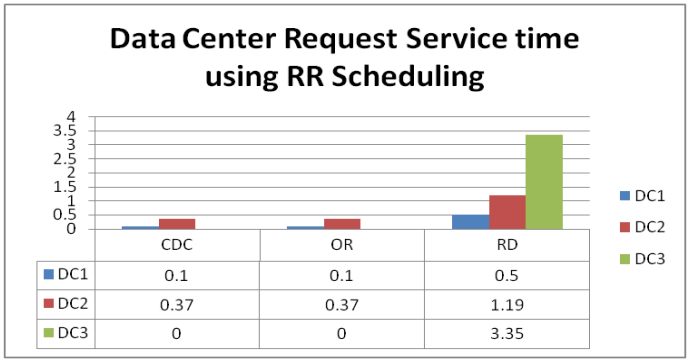

Fig. 5. Data Center Service Times using RR Policy.

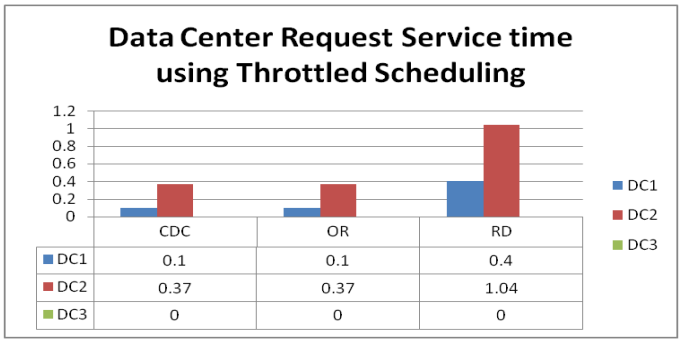

Fig. 6. Data Center Service Times using Throttled Policy.

Therefore, for the consumers, it must be decided by them on which service they need as their requirements are different. Some consumers might want the response time to be less as they wish their tasks to get processed faster irrespective of the payment charged while there might be other groups of consumers, who are not bothered about the speed of the execution but are concerned much with the amount.

V. Conclusions

Task scheduling is done under two strategies one being preemptive and the other being non-preemptive. This study analyzes the characteristics of different scheduling techniques used in both environments. Before the resources are allocated, the availability and the accessibility to those resources are estimated. One of the promising challenges is load balancing in cloud computing. Addressing this challenge will reduce the burden at the data center, and this time can be better utilized in

processing. The behavior of two of the resource scheduling policies, Round Robin and Throttled are compared under different service broker policies. The metrics, like the response time at each user base and processing time at each data center, are used. The simulative results show that the response time for the userbase3 under RR is very low as the load is considered dynamically and the tasks are executed. The data center service times are high in both the scheduling policies using reconfigure dynamically as the service broker policy, while with the other two are the same. The metrics used help us to conclude that if the tasks are to be executed faster and then the load is to be reconfigured and is to be allocated to the free datacenter, wherein it increases a little overhead. This information may guide the consumers to take appropriate decision in signing the SLA.

VI. Future Work

The authors have studied the behavior of two of task scheduling algorithms and compared them under different service broker policies. But still there is a scope to modify these algorithms according to the requirements and analyze its behavior. A new hybrid method can also be proposed to better satisfy the customers and improve the performance metrics. The overhead incurred while performing load balancing can be reduced further by using either traditional techniques or by using machine learning techniques, which is carried as future work.

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Assessing Assistive Learning Technologies with Experimental Design

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***Abstract*—Assistive learning technologies are generally computer-based instruments which are focused at supporting individuals with disabilities in enhancing their learning session with minimal intervention of parents, guardians, as well as helpers. Assessments using experimental research design have frequently been utilized in order to evaluate their efficacy along with feasibility. An experimental design is categorized by experimental units or treatment to use, the tendencies that are tested, as well as the way treatments are designated to units. The experimental or treatment units need sufficient a number of and representative respondents or sample. Even so, due to the limited numbers of sample units or respondents, such type of experiments is noted as subtle yet challenging experiences. Based upon our substantial encounters, this article tries to disclose such precious research experiences.**

***Keywords*—Assistive learning technology; disabilities; experimental design; mathematical learning; serious games; autism; visual perception**

I. Introduction

Assistive Technologies (AT) are generally known as items, product systems or pieces of equipment, regardless if acquired commercially, altered, or tailored, which was utilized to improve, sustain, and also enhance functional skills of people with ailments [1]. Assistive learning technologies consist of computer-based instruments which are targeted to support individuals with disabilities in enhancing their learning with minimal intervention of guardians [2]. Additional investigation from the equivalent reference discovered that around 80 percent of released reports on AT executed to analyze the efficiency of the employment of AT in influencing respondents' capabilities and almost 50% of these studies utilized experimental design [3].

Implementing experimental design for the assessments of AT efficacy is exclusive, fragile and challenging experiences [4-6]. Participants of the studies are individuals or youngsters with disabilities, for instance partially strokes or with Autism Spectrum Disorder (ASD). Moreover, there were various issues associated with attaining access, parent or guardian concern or approval, legal issues, along with reporting the discoveries [7-8] which affect the experiment's scope, paradigm, as well as the experiment data analysis.

In the subsequent Sections 2 and 3 of the article, the evaluations on experiences are pursued according to two chosen trials, which are a mathematics tutor, known as MathTutor, as well as a serious game diagnosis, known as Vi-Per Games, for children with autism. For each trial, the experimental design and setting used are explained. Besides that, the results gained from each trial are discussed. Next, Section 4 concludes this article and describes the recommendation for future research.

II. MathTutor Trial

A. Design and Setting

This study focused primarily to evaluate the effectiveness of a Computer-Assisted Instruction (CAI) or tutor in assisting students with autism to master basic ideas of addition concept. In order to get the finest outcome from the trial, pre-test and post-test design of experiment was intended for the population of Malaysia resident, youngster with autism.

In order to do the experiment, a consent was requested from associated authorization bodies to access the facilities of guardians or schools. Even so, the consent could not be obtained for several months up to the point the population were switched to the youngster with autism in Melaka. Furthermore, during the stage of choosing respondents, basic data concerning the potential respondents were gathered by conducting pre-interviews with the educators.

Afterwards, validates if they possess the desired abilities for the experiment done by an observation. The respondents were needed to possess specified precondition abilities for instance to be able to comply with instructions orally or

written, being capable of understanding numbers between 1 and 10, knowing how to work with laptops and mouse, and also being able to give attention to the activity no less than 10 minutes.

Next, 40 (forty) students diagnosed with autism who acquiring the desired abilities were chosen as respondents for the experiment at the end of the observation phase, by which they were separated into two different groups randomly; the control group that used teacher-assisted learning method, and the intervention group in which utilized the MathTutor. They were from a few primary schools in Ayer Keroh, Melaka.

Fig. 1 portrayed the design of the experiment. For this study, *O1* and *O3* signify the pre-test process employed to acquire data on respondent levels of addition concept on two separate groups whereas *O2* and *O4* are the post-test procedure. *P* refers to the control group of the experiment which were employed the regular tutoring system through the entire experiment. In the other hand, *X* is the intervention group which employed the MathTutor during the experiment.

Later, the study was conducted in an individual education class room. Throughout the experimental period, there was none other individual in the class room apart from the respondent and the researcher. Throughout the experimental session, the intervention modules which have been designed were displayed in the tutor using a laptop. Minimal guidance and prompt were present to the respondents whenever they were unable to comply with the verbal or written instructions.

B. Results and Discussion

This particular section reviews the overall achievement of respondents through the entire experiment. In order to measure the tutor's potency as a learning instrument, a pre-test and post-tests had been performed within the experiment. Prior to starting the experiment, each of the respondents were instructed to take a pre-test as a way to identify their initial level of skill before treatment. To conclude, after the final session, the respondents were needed to take post-test, in which the questions were identical to the pre-test.

The control group of the experiment were employed the regular tutoring system through the entire experiment in which included 20 students with autism which were choose randomly. In order to evaluate if there is a substantial improvement amongst the pre-test and post-test results of the control group, the Wilcoxon Signed-Rank Test [9] was employed. In conclusion, the Wilcoxon Signed-Rank Test effectively identified the important different concerning the pre-test and post-test achievement within the control group ($Z = -3.91$, $p < 0.05$). The outcome pointed out that a significant different did occurred for the control group achievement. To be exact, a significant variance was found between the pre-test and post-test scores in calculating the control group's skill level.

O_1	P	O_2
O_3	X	O_4

Fig. 1. Design of MathTutor Experiment.

In addition to that the distribution of pre-test and post-test scores of the respondents from the control group was reflected using scatter plots. The plot reveals 90% of the pre-test scores had been allocated under 50% score. Thus, 90% from the respondents have scored equivalent to or lower than 50% score. Apart from that, this plot also demonstrates the post-test scores, highlights around 35% from the respondents achieved over 60% score in which indicates approximately 60% from the respondents achieved high post-test scores (between 60% and 80%). Thus, presenting enhancement before and after the experiment within the control group.

During the experimental case study, the intervention group included 20 students diagnosed with autism who were chosen randomly, by which the respondents experienced the tutor that determines the suitability of learning content according to the users' degree of proficiency through the entire experimental case study. Consequently, the Wilcoxon Signed-Rank evaluation was applied to evaluate if there is a substantial improvement amongst the pre-test along with post-test scores of the experiment group. In conclusion, the outcome discovered a substantial variance amongst the pre-test and post-test scores resulting from the experiment group ($Z= -3.92$, $p<0.05$). This outcome suggests that a significant different have occurred within the experiment group. Hence, an important variance was discovered amongst the pre-test and post-test scores in calculating the skill's level within the intervention group.

The experimental case study was performed to look for the significant variance between the control and intervention groups. Consequently, the post-test marks extracted from each group had been utilized to discover the outcomes of the experiment. Mann-Whitney U test has been utilized to correlate the skill's level amongst respondents within the experiment group, specifically exploring into their fundamental addition concept in mathematics at the end of the experimental case study, apart from ensuring the existence of an essential divergence involving the post-test scores extracted from the control as well as intervention groups. In addition, the discoveries of the Mann-Whitney U test considering the purpose of figuring out the important difference between post-test scores of the control and intervention groups.

Additionally, it describes the fact that post-test rank average of the control group is 11.10, whilst the intervention group is 29.92. Therefore, a massive variation of 18.82 points is reported amongst the rank averages of each group. According to the evaluation conducted, the figure of ($U = 11.50$, $p<0.05$) attained signifies a rather notable variance involving the control along with intervention groups. Basically, the technique introduced to the intervention group verified to be more beneficial, compared to the method employed in the control group.

An informal observation has been executed on both experiment and control groups throughout the experiment. The observation was conducted whenever respondents attempted using the tutor. In addition, information was documented from the observations associated with their behaviour, development, and if they had needed assistance or guidance.

Throughout the first session, all the respondents displayed some curiosity about utilizing the computer or laptop as a learning instrument to learn the addition skill even though few appeared playful and required assistance to remain concentrated at the beginning period of the session. Apart from that, a number of the respondents demanded assistance or guidance when reaching reinforcement exercises, particularly with questions that included numbers bigger than five.

Within the second session, several respondents demonstrated that they able to recall the lesson learned previously. Besides using the pictures presented with the questions, some of respondents counted using fingers. In spite of that, some respondents continue to repeat the same mistakes they did previously. Additionally, most of the respondents appeared interrupted by the audio from the answer button. Thus, throughout this period, several respondents required assistance and guidance, particularly when answering reinforcement exercises.

Afterwards, during the third session, the majority of the respondents demonstrated to be able to recall the lesson learned in previous session. Furthermore, majority respondents were able to concentrate on both learning as well as assessment during this session. However, some respondents had required guidance, and a few others needed both assistance as well as guidance during calculations. In fact, majority of the respondents likewise appeared to have fun with the learning period and asked to repeat the lesson.

In the meantime, in the fourth session, most of the respondents exhibited motivation and curiosity through the lesson, even though several happen to be diverted by the audio from the answer button. Throughout this session, almost all respondents only needed guidance whenever attempting the calculations. Additionally, they appeared to have fun with the session and wanted to repeat the session.

Next, in the fifth session, identical to the prior session, the majority of respondents demonstrated motivation and curiosity throughout the lesson, however a few ended up diverted by the audio from the answer button. As a result, those distracted had wanted assistance and direction while answering reinforcement question.

During the sixth and the last sessions, almost all respondent appeared wanting to begin the learning lesson. On top of that, the majority of respondents were capable to achieve the exercise efficiently, even though only several needed minimum guidance instructions throughout reinforcement exercise. The respondents also appeared to have fun with the learning period and wanted to repeat the session.

On top of that, throughout the experiment, the majority of the respondents shown enhancement in behaviour as they retained excellent behaviour throughout the entire remaining experimental learning session, compared to the initial two sessions. The respondents also demonstrated that they loved the learning period in which they asked to repeat the lesson and frequently asked to use the computer. Hence, the approach utilized in the tutor, for instance pictures, animated graphics, and also audio, appeared to catch the attention of these students with autism, other than maintaining their concentrate while learning took place. Consequently, the tutor had been proven to boost both involvement as well as curiosity among students with autism throughout the sessions. Additionally, all of the respondents actively took part throughout the learning session, in which they counted along with the tutor. Therefore, the respondents were intrigued to follow the learning sessions and wanted the lesson to be repeated. Apart from that, the tutorial along with the examples presented to them gained their interest, hence assisted them in memorizing the lesson learned [24].

III. Vi-Per Games Trial

A. Design and Setting

Early recognition and examination to youngster with autism is necessary to expose these individuals with early intervention program in an effort to overcome, or to lessen at least, the difficulties relating to autism. This study aimed to build up serious games, named Vi-Per Games, as an instrument for special education teachers and guardians to examine visual perception difficulties in students with autism. The Chalfont diagnosis principle has been utilized for production of the instrument [10]. In an effort to accomplish exterior validity of the model of experimental research, a trial was developed for the population of students or youngsters diagnosed autism in Johor. As above, attaining access was started from special classes or centres of therapy of youngsters or students with autism. Despite the fact that the access was given within the long-term excess limit, yet there are merely a few respondents who were capable to be a part of the research due to the fact that only some of the guardians or parents return the concern forms. Eventually, only 10 (ten) students are keen to be the research respondents.

This research employed the mixed approach, applying both quantitative as well as qualitative approaches. The application of qualitative technique employed in this study is to verify the model as well as the perception of teachers in regards of the application of the serious games for diagnosing visual perception difficulties in students with autism. Alternatively, the quantitative technique is to verify the reliability of the serious games for examining and producing systematic and extensive analysis reports on visual perception difficulties in students with autism.

This section also addresses the features of research design, such as the tool employed in this research. ADDIE model is utilized as the research design to build up the visual perception diagnostic instrument. This five-phase systematic model, known as Analysis, Design, Development, Implementation and Evaluation, is employed to steer throughout the steps involved in developing multimedia products for all kinds of framework. Each phase offers a course of tasks that assist to ensure production initiatives remain on time, on track and on target. Finishing each stage sufficiently boosts the opportunity that the data displayed essentially continues to be relevant to the requirements of the investigation. Selection of the respondents can be viewed as a purposive sampling. In accordance with Bogdan & Biklen [11] and Chaudary [12] since the respondents were recognized and chosen according to some purposive key points for instance accessibility, thus the selection of the respondents can be treated to be purposive

sampling rather than random sampling. Additionally, precise information extracted from the respondents was best suited to the objective of the research.

The information was gathered with the contribution of special education school teachers as well as students diagnosed with autism of SMK Tun Syed Nasir Ismail and SMK Bandar Baru Uda, both are high schools located at Johor Bahru. The information associated with the gathering approaches employed in this evaluation is also analyzed and explained. Information regarding visual perception level of each respondent are ordinal type. They were assigned or coded an ordinal scale dimension. The Wilcoxon Signed-Rank test was utilized in each sample in verifying no substantial improvement between respondent conventional as well as Vi-Per Games test outcomes. In the meantime, data that illustrate the respondent understanding, figure on utilizing the comment, prototype, and general associated results are nominal and/or ordinal type. To achieve the goal of data evaluation, descriptive statistics for instance percentiles, median, and percentage were used. Generally, this study consists of the emergences of the Vi-Per Games system for the diagnosis of visual perception for students with autism apart from how special education teachers employed these games in the classroom. Additionally, at the beginning stage, a diagnostic test was obtained by the respondents. Besides, this technique has also been identified for this research and explains the research design, research strategy, data collection, sampling strategy, along with the research data evaluation.

B. Research Approach

Main ideas of research domain require details knowledge about research technique. In accordance with Brewer et al. [13], quantitative research is known as hypothesis testing research whereby research start with statements of idea extracted from the research hypotheses. Furthermore, a qualitative research technique according to interviews, document reports, and observations extracted from real life is argued in order to fulfil the investigation goals. Nevertheless, several other research strategies were also be reviewed. From literary works and discussions on numerous traditions and strategies to "good" analysis [14-17], four prospective research techniques have been regarded for the study. There is quantitative experimental research, qualitative observational research, participatory action research as well as logical theoretical research. Two types of strategies were employed together with research techniques, which are qualitative technique with questionnaires and quantitative technique with experiment. The result was accumulated by utilizing the survey technique as well as using a questionnaire to obtain the views of the sample population. Malhotra [18] and Sekaran [19] reported that gathering information for a survey can be assisted by face-to-face sessions. In addition, observations, e-mails, telephone interviews, personally administered questionnaires or the Internet can help to accumulate the data required. Then, the Likert scale, a well-known approach to accumulating data regarding surveys was employed. This technique is utilized to determine behaviour. It needs respondents to give responses to a series of statements. According to Saunders et al. [20], the responses range from highly agreed to highly disagree. Thus, the Internet and personally administered approaches were regarded as the utmost relevant technique to acquire the information.

In this research, qualitative and quantitative techniques were chosen. The qualitative research employed in this research is to verify the model as well as the teachers' perception towards the implementation of the serious games in order to diagnose visual perception difficulties in autistic students. While the quantitative study utilized in this study is to verify the precision of the serious games for diagnosing visual perception issues in autistic students and produce extensive and organized analysis reviews of visual perception difficulties.

To illustrate how the prototype was applied, a separate sample pre-test and post-test accompanied by a case study design was used. The respondents were divided into independent sample sizes of 3, 3 and 4. Kerlinger [21] and Tuckman [22] explain one group pre-test and post-test pre-experimental structure as shown in Fig. 2.

A measurement or observation is specified as O while a treatment or the occurrence of the treatment is specified as X. Each O has an arbitrary subscription to facilitate referral and recognition. In this research, to offer some details regarding the sample of respondents, measurement or observation O1 was completed by implementing pre-test or survey. Next, a treatment X was tested on the subjects. Lastly, an additional measurement or observation O2 was performed on the group members to access the consequences of treatment X.

The one group pre-test and post-test was employed thrice in order to conquer the history bias that was the primary inherent insufficiency in this design [22]. The phrase history bias refers to the assumption produced by occurrence happen simultaneously in the environment when testing the experimental variable. Pramudya [23] revised design, in which recognized pre-test and post-test design of separate samples is highlighted in Fig. 3.

For this research, *O1*, *O3*, and *O5* consecutively signify the pre-test process employed to acquire data on respondent levels of visual perception analysis by implementing the standard approach by Ministry of Education Malaysia, Visual Perception Diagnostic Test Instrument on three separate samples. *X* is the instructional treatment used for the Vi-Per Games prototype, and *O2*, *O4* and *O6* are the post-test procedure. Questionnaires and information of student with autism statistics in the database were utilized to accumulate details of the level of visual perception of the respondent, the teacher opinion of the prototype, and additional general relevant feedback from the three samples after the treatment.

$$O_1 \qquad X \qquad O_2$$

Fig. 2. Design of Vi-Per Games Experiment.

$$\begin{array}{lll} O_1 & X & O_2 \\ & O_3 & X \\ & & O_5 \end{array} \qquad \begin{array}{ll} & \\ & O_4 \\ X & \end{array} \qquad \begin{array}{l} \\ \\ O_6 \end{array}$$

Fig. 3. Separate-Sample.

C. Results and Discussion

The outcomes of the three distinct samples reveal that there were no considerable dissimilarities in this research between the pre-test and also the post-test scores of respondents. It demonstrates that, within each sample groups, the respondent's pre and post-test scores were identical. As the collection of scores was conducted in three different distinct samples on distinct timelines, the history bias in this research was prevented. That is to say it is less likely that some other occasion would have happened concurrently in the three samples to impact the implement of the serious game setting. This sustains the final outcome that the evaluation scores generated by applying the serious games are precise. In which indicates that the serious game technique by utilizing Vi-Per Games as a substitute technique may gave advantages to the students with autism as well as teachers in the examination of the visual perception level of students with autism.

Since Vi-Per Games could enhance the diagnostic procedure, motivate students, and boost their curiosity as well as inspiration, these games can be adopted to aid students with autism to endure diagnostic testing. Evidently, these discoveries are coherent with a prior study, which likewise point out student with autism compatibility with games. Additionally, the discoveries also emphasize that games can assist to assess the performance of visual perception.

IV. Conclusion

This article is supposed to examine encounters on implementing experimental design in two distinct scientific studies. The key purposes of the researches were to analyze the efficiency regarding two AT known as MathTutor as well as Vi-Per Games in aiding students with autism to acquire the elementary mathematics principles of addition and aiding guardians to analyze children with autism. Associate samples were developed to be able to fulfill the layout's external validity or to generalize the discoveries. Nevertheless, due to the restricted concern from the parents, guardians or guardians of the youngster along with minimal accessibility obtained, only small-scale samples or respondents are used. This pressured the researchers to modify the scope, paradigm, as well as the research data analysis. Therefore, more examples of experimental design setting for small number of samples from studies on using AT for children with disabilities may enrich knowledge and experiences in this field of experimental design.

Acknowledgment

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Feature Fusion: H-ELM based Learned Features and Hand-Crafted Features for Human Activity Recognition

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***Abstract*—Recognizing human activities is one of the main goals of human-centered intelligent systems. Smartphone sensors produce a continuous sequence of observations. These observations are noisy, unstructured and high dimensional. Therefore, efficient features have to be extracted in order to perform an accurate classification. This paper proposes a combination of Hierarchical and kernel Extreme Learning Machine (HK-ELM) methods to learn features and map them to specific classes in a short time. Moreover, a feature fusion approach is proposed to combine H-ELM based learned features with hand-crafted ones. Our proposed method was found to outperform state-of-the-art in terms of accuracy and training time. It gives an accuracy of 97.62% and takes 3.4 seconds as a training time by using a normal Central Processing Unit (CPU).**

***Keywords*—Hierarchical extreme learning machine; kernel extreme learning machine; deep learning; feature learning; human activity recognition; feature fusion**

I. Introduction

Recognizing human activities is one of the main goals of human-centered intelligent systems. Human Activity Recognition (HAR) is a type of system that automatically observes human activities and maps each activity to its corresponding class. It is connected to different applications such as machine computer interaction, entertainment devices and health monitoring. It plays an important role to permanently monitor children and elderly people by using home-based services.

Different data acquisition devices such as smartphone sensors (Accelerometer and Gyro) [1, 2] were used to collect information about the activities. Different activities are classified and recognized by utilizing this data. Sensor based activity recognition is a difficult task because the sensory data is noisy, unstructured, and high dimensional. Therefore, the process of building a classification model is not an easy task.

In the previous works of HAR, features were usually extracted independently from multiple sensors (accelerometers and gyroscopes) in a handcrafted way [1]. Different classifiers were used for classification such as Support Vector Machine [1, 3], Random Forest [4] and Hidden Markov Model [5]. Extreme learning machine (ELM) and back propagation neural networks were also used as classifiers in HAR system [6, 7].

Recent methods of deep learning such as convolutional neural networks (CNN) [8] and stack of auto encoders [9] focus on automatic feature learning. They were used to recognize different activities [2, 10]. In few applications, sensory signals were not used directly. In other words, signals from accelerometers and gyroscopes were assembled into an activity image [2]. This enables Deep Convolutional Neural Networks to automatically learn the optimal features and give an accuracy of 95.18% [2]. Various unsupervised feature learning methods were demonstrated to learn representations from accelerometer and gyroscope [10]. These techniques include Sparse Auto Encoder (SAE), and De-noising Auto Encoder (DAE). The SAE channel-wise extractor was found to outperform other techniques with an accuracy of 92.16% [10].

Hierarchical extreme learning machine (H-ELM) [11] is a fast-deep model that is utilized for automatic feature learning. In this mode, the speed of learning is high because the weights are not fine-tuned iteratively. The biases and input weights are given random values. The analytical calculation of output weights is also done. H-ELM was compared with other deep models such as CNN [12]. It was found that H-ELM is able to outperform some architectures of supervised CNN in term of training speed by using CPU in low cost human detection system. The H-ELM was able to solve the trade-off between the accuracy and the training speed.

Feature extraction technique (i.e. dimensionality reduction) is utilized to get important and informative features from a set of data measured by different sensors. The power of this step lies within its impact on other steps such as generalization and classification. When high dimensional data is classified, the overfitting problem is raised. To avoid this problem, Feature learning is a key solution. Our proposed method of feature fusion does not depend only on traditional handcrafted features. It also learns the data representations (features) automatically by a deep learning model. The combination of learned and hand-crafted features requires a classifier that has high performance in generalization. Kernel Extreme Learning Machine [13] is the key solution as a candidate classifier in the proposed system.

This paper proposes a combination of H-ELM based learned features and hand-crafted features. Fig. 1 illustrates the block diagram of the proposed architecture. We have built and tested various architectures of HELM to choose one that gives the best accuracy and increases the training speed. The proposed method was found to outperform state-of-the-art in terms of accuracy and training time. It gives an accuracy of 97.62% and takes 3.4 seconds as a training time by using a normal Central Processing Unit (CPU).

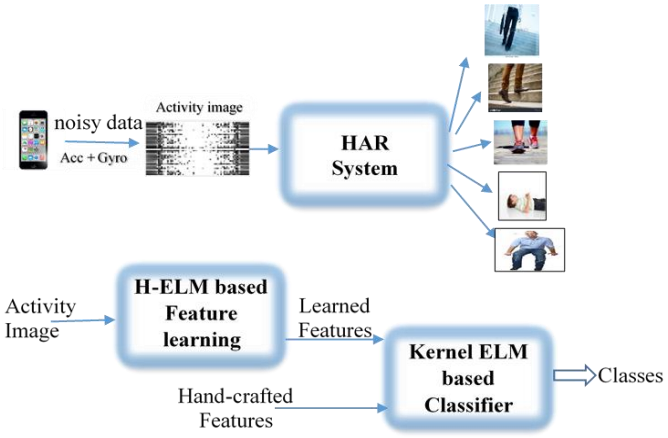

Fig. 1. The Block Diagram of the Proposed System.

The main contribution of this work is the ability to implement the HAR system on a low-cost embedded system that has a normal CPU. Above that, the HAR system was able to recognize activities in real time by speeding up the learning and utilizing ELM based sparse auto-encoders. The recognition accuracy was also improved with the advantage of feature fusion.

The organization of this paper is as follows: In Section 2, the methodology of the proposed model is discussed for HAR feature learning and classification. Section 3 describes the experimental results and analysis in terms of accuracy and learning time. In Section 4, a summary of work outcome and future works are mentioned to demonstrate the efficiency of the proposed system.

II. Methodology

A. Extreme Learning Machine

Basic ELM (Extreme learning machine) is a shallow neural network with only one hidden layer. This network has attracted researchers because the learning time is low with very good generalization [14]. The parameters (biases and weights) in the hidden layers are given random values. The weights of output are found analytically.

$$f(x) = \sum_{i=1}^{L} F_i(x, W_i, b_i).\ \beta_i \quad , \quad W_i \in R^d \quad , \quad b_i, \beta_i \in R \qquad (1)$$

Where Fi (⋅) is an activation function of i_{th} hidden node, W_i is an input weight, b_i is a bias, and βi is a weight of output, L neurons in the hidden layer are used.

$$\beta = U^{\dagger}T \quad , \quad \beta = U^T\left(\frac{1}{\lambda} + U.U^T\right)^{-1}.T \qquad (2)$$

Where matrices are: U is an output of hidden layer, U† is the Moore–Penrose generalized inverse of a matrix, T is a target and λ is a regulation coefficient.

B. Hierarchical Extreme Learning Machine for Feature Learning

Sometimes the data is not simple and requires more processing before being applied to a classifier. For visual data such as images, a raw data should be processed to extract or learn features. A hierarchical architecture of ELM can do the job [11]. Hierarchical extreme learning machine (H-ELM) is a recent deep model that is used for automatic feature learning. H-ELM includes two blocks: unsupervised and supervised training. The supervised training is done by the basic ELM. The main block in unsupervised learning is elm-based sparse auto-encoder which can achieve self-taught feature learning. H-ELM has a good generalization and a high-speed learning. In this model, an elm-based sparse encoder is utilized. Fast Iterative Shrinkage-Thresholding Algorithm (FISTA) was used to build this encoder which is considered as a main block in H-ELM. To get deeper architecture, multiple encoders are stacked. In order to increase the testing speed, the number of neural nodes should be reduced. The model guarantees good data recovery. For more details, you may have a look on H-ELM paper [11]. H-ELM works with random parameters that shouldn't be fine-tuned iteratively. The advantage of the previous concept is the high speed of learning and training. The input weights of ELM based sparse auto-encoder are generated randomly. L1 optimization is used instead of L2 norm (utilized in traditional ELM auto-encoder) to give better data recovery. This is important to have more sparse and compact features. Fig. 2 illustrates the overall framework of H-ELM and its single layer.

C. Kernel ELM for Classification

Kernel ELM can handle sparse data sets [13]. Its speed is more than Least Square-Support Vector Machine (LS-SVM) by an order of magnitude. Kernel ELM has a better generalization than Kernel SVM.

$u\ (x)$ is a mapping for features, $\Omega_{ELM_{i,j}}$ is a kernel matrix which has a relation with the data of input and the size of training data.

$$\Omega_{\mathrm{ELM}} = U.U^T\ ,\ \Omega_{\mathrm{ELM_{i,j}}} = \mathrm{u}(x_i) \cdot \mathrm{u}(x_j) = \mathrm{K}(x_i, x_j) \qquad (3)$$

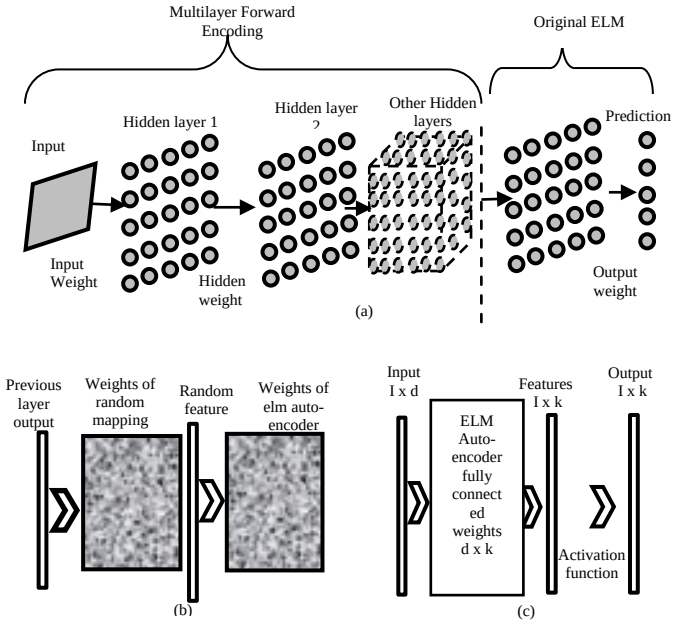

Fig. 2. (a) Overall Framework of H-ELM. (b) Sparse ELM based Auto-Encoder. (c) Layout of Single Layer in the H-ELM [11].

The K-ELM classifier output is [13]:

$$f(x) = u(x).U^T \left(\frac{I}{C} + U.U^T\right)^{-1}.T =$$

$$\begin{bmatrix} K(x,x_1) \\ . \\ . \\ . \\ K(x,x_N) \end{bmatrix}^T \left(\frac{I}{C} + \Omega_{\text{ELM}}\right)^{-1}.T\,, \quad (4)$$

C is a regularization coefficient

where $K(x_k, x_j) = exp\left(\frac{-(||x_k - x_j||^2}{\sigma^2}\right)$ is a Gaussian kernel, σ is a kernel parameter.

D. Activity Image

Most of smartphones contain a gyroscope and an accelerometer. Angular velocity and tri-axis acceleration are measured by these sensors. The data of these sensors is utilized to classify human activities. The sequences of this data are high dimensional and need to be represented efficiently to get better results. In our experiment, both of accelerometer and gyroscope were used. An activity image that is based on signals of gyroscope, total acceleration, and linear acceleration was proposed in [2]. A signal image that has a stacked row in a specific order according to specific algorithm was used. After that, signal images were transformed by using two-dimensional Discrete Fourier Transform. The amplitudes of resulted images are named as activity images. Fig. 3 shows activity images for different activities.

Fig. 3. Activity images for different activities.

III. Experimental Results

A. Dataset

In this research, UCI Machine Learning Repository dataset was used for activities recognition task [1, 15]. A group of 30 people with 19 to 48 ages was the target. Each participant has a Samsung galaxy smartphone on his waist. Six different activities were chosen: walking in three states: normal, upstairs and downstairs, laying, standing, and sitting. The experiment was repeated twice. Refer to [1, 15] for more details. The sensors used in this work were accelerometer and gyroscope with sampling rate of 50Hz. The signals of linear accelerations and angular velocities for three axes were recorded. The experiments were running on a desktop computer (CPU: Intel Core i7 @ 3.5 GHz) with Windows 8.1 x64. The number of training examples is 7352. The number of testing examples is 2947.

B. The Hand-Crafted Features

A set of 561 features was produced for one activity [1]. The extracted features were collected in frequency and time domains. Different measures such as correlation, frequency energy and angles between vectors were selected as discriminative features. The list of these features is available in [15, 16, 17].

C. The Learned Features

Different Hierarchical ELM architectures (various hyper-parameters such as number of hidden nodes and layers) were built and tested. The objective is to select the architecture that has the best performance in term of accuracy for activity classification. The architecture in Fig. 4 has the best accuracy. The input is one activity image for each activity with 68*36 = 2448 elements, where 68 is the number of signal samples and 36 is the number of different signals organized in a specific order. For more details on how these numbers were selected, please refer to [2]. The H-ELM model was utilized to learn 500 features which are the number of neurons in the hidden layer. These features were produced from the output of ELM based auto-encoder. Basic ELM classifier was removed from the last layer.

D. The Proposed Architecture of Features Fusion

The feature fusion was achieved by combining the learned features in the hidden layer of H-ELM which is x_{HELM} = 500 with x_{HF} = 561 of features produced in a handcrafted way. The output of the fusion feature layer can be written as:

$$x_{\text{Fusion}} = [x_{\text{HELM}}, x_{\text{HF}}]$$

The final vector x_{Fusion} is entered to the kernel ELM which was used as a classifier to produce six classes for six different activities.

The experiments were implemented in Matlab2016a on a desktop computer running Windows 8.1 (64 bits) environment. The Intel core i7 @ 3.5 GHz CPU was utilized to run the program of the proposed method.

E. Accuracy Analysis

Table I compares the performance of the proposed method and that of state-of-the-art. In some works (grey color fields in the table), the input of model is the values from different sensory channels. These values were collected and applied to the classifier. They used various deep models such as stacked Auto Encoders (SAEs) and De-noising Auto Encoders (DAEs) [10]. In our work, we have applied H-ELM on this collection of different channels. The obtained accuracy was found to be better than that of SAE, DAE and Principle Component Analysis (PCA). H-ELM produced better accuracy with 500 hidden nodes (91.31%) than one of 128 nodes (90.77%).

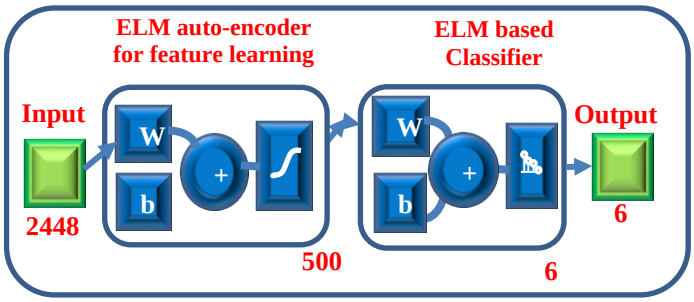

Fig. 4. Hierarchical ELM based Model.

In white color fields of the table, the input of model is an activity image. H-ELM was also demonstrated to learn features from this activity image. It gives good accuracy of 94.5%. The proposed combination of handcrafted and automatic learned features (H-ELM+) outperformed the existing HAR methods in term of accuracy that arrives to 97.62 %. The confusion matrix of testing is shown in Fig. 5. In Table I, the comparison with deep convolutional neural network (DCNN) [2] is shown. The same input which is an activity image was applied. The DCNN extracted the structure of the activity image. Hand-crafted features in DCNN+ were also used to aid and complement the learned features when the activity image is not confident.

Table II compares the performance of basic ELM, Kernel ELM, SVM and feature selection classification methods by using only handcrafted features.

TABLE I. COMPARISON BETWEEN STATE OF THE ARTS DEEP MODELS AND THE H-ELM MODEL

Methods	**Accuracy %**
DAEs-m [10]	82.78
SAEs-m[10]	83.81
PCA-m [10]	89.79
H-ELM_m with 128 hidden nodes (ours)	**90.77**
H-ELM_m with 500 hidden nodes (ours)	**91.31**
DCNN [2]	95.18
DCNN+ [2]	97.59
H-ELM (ours)	94.5
H-ELM+ (ours)	**97.62**

Fig. 5. The Testing Accuracy (Confusion Matrix).

TABLE II. PERFORMANCE COMPARISON BETWEEN STATE OF THE ARTS CLASSIFIERS AND K-ELM BY UTILIZING HANDCRAFTED FEATURES

Methods	**Accuracy %**
Feature selections [17]	94
SVM [1]	96
Basic ELM (ours)	96.1
Kernel-ELM (ours)	**97.15**

Fig. 6 illustrates the bar plot to compare between different deep learning models applied on sensory channels and activity images. Fig. 7 visualizes the comparison between different classifiers with hand crafted features. Fig. 8 and 9 show the accuracy of K-ELM classifier with different regularization coefficients C and kernel parameters σ.

F. Speed Analysis

Table III compares between two feature learning models (H-ELM and Stacked Auto Encoder [9]) in term of training time. The proposed H-ELM based method outperforms SAE in term of training speed. The reason behind that is the ability of H-ELM to generate random parameters that are not fine-tuned iteratively. This fast deep model can reduce the time of training by an order of magnitude. Fig. 10 shows the difference.

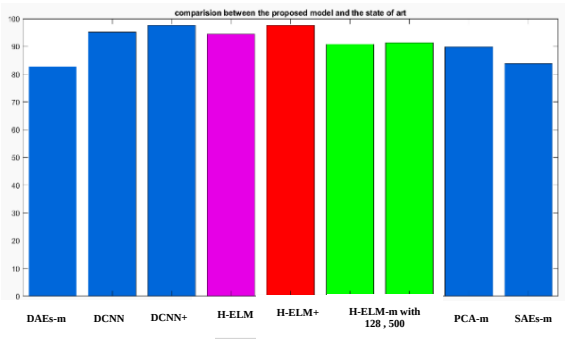

Fig. 6. The Accuracy of Methods in Table I. Compared to ours.

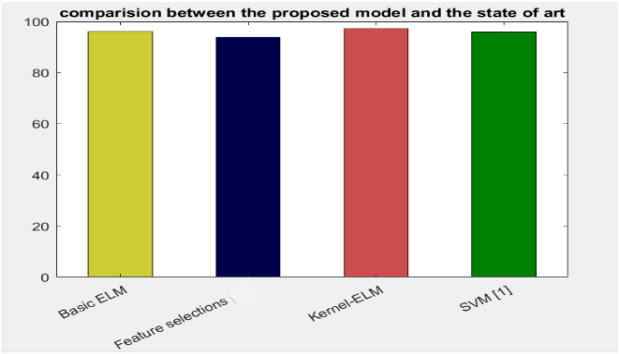

Fig. 7. The Accuracy of Methods in Table II. Compared to ours.

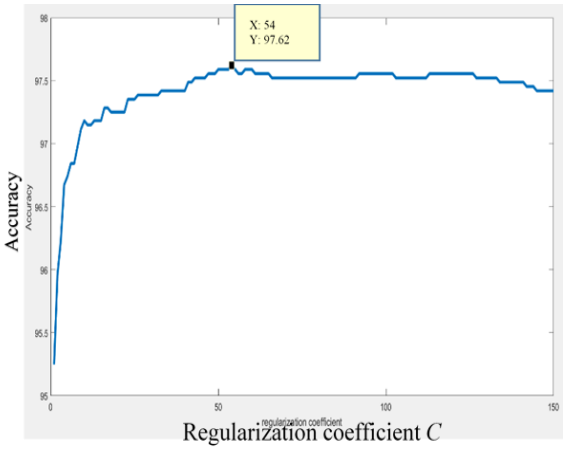

Fig. 8. The Accuracy for Various Regularization Coefficients.

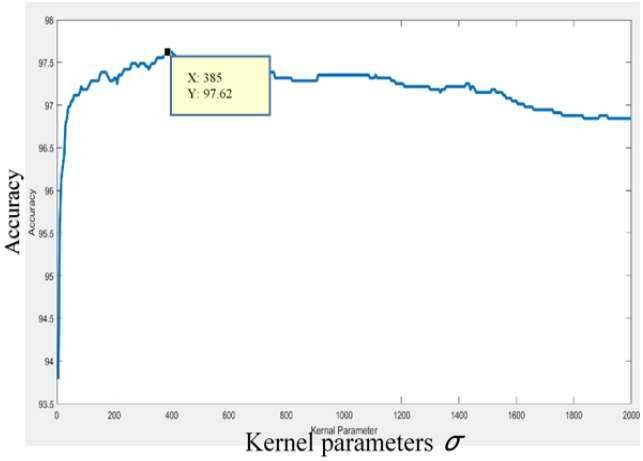

Fig. 9. The Accuracy for Various Kernel Parameters.

TABLE III. TIME OF FEATURE LEARNING FOR H-ELM AND TRADITIONAL STACKED AUTO ENCODERS

Method	Total Training time (s)
Stacked Auto encoder [9]	840
H-ELM	3.4

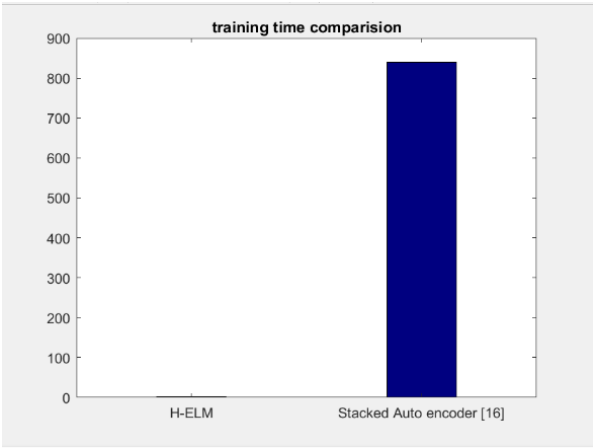

Fig. 10. The Training Time of H-ELM vs SAE.

IV. DISCUSSION AND CONCLUSION

In this paper, the application of smartphone sensors based human activity recognition is addressed. Automatic feature learning was achieved by H-ELM with a little training time. Fourier based activity image was used as an input to H-ELM model. A combination of hand-crafted and H-ELM based learned features was demonstrated to improve the system performance. The results were compared with state of the arts on UCI dataset. The proposed method was found to outperform other existing methods in terms of accuracy and time efficiency.

The work results are summarized as follows:

- H-ELM is an effective model in HAR system for automatic feature learning in a short time. Compared to a stack of auto-encoders, H-ELM doesn't need to fine tune the weights iteratively.
- Feature fusion can build a robust activity recognition system with a high accuracy.
- K-ELM has a high generalization for activity classification by utilizing both hand-crafted and learned features.
- The existing CNN models utilize Graphical Processing Unit (GPU) to reduce the training time. Using CNN with CPU leads to low training speed. A low-cost embedded system has usually a normal CPU. The advantage of the proposed method is its ability to be implemented on a normal CPU with high speed training.

This work focuses on learning features of sensory data of accelerometers and gyroscopes using UCI dataset. This may open the door to future work by utilizing the proposed model with other datasets such as UCF. UCF dataset uses a video camera as a sensor to classify videos of various human activities. The concept of feature fusion also spots the light on the importance of combing learned and handcrafted features to reduce the probability of overfitting and increase the test accuracy. Applying feature fusion on other sensory data such as images or audio files may have a significant impact on system's performance.

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Comparison Shopping Engines

State of the Art, Exposure of Shortcomings and Discussion of New Innovations

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Abstract—Since the stimulation of both feelings of need and temptation have become excessive with the spread of internet advertising, the e-consumer have begun to feel increasingly lost and overwhelmed by offers in a purchasing cycle whose process is mostly unstructured, unguided, and unassisted or - in other words - non user-friendly. As a result, he displays a confused and suspicious attitude and desperately turns to the comparison shopping engines (CSEs) to save time and identify the best matching offer for his search request. Thus, the article in question serves as an investigation of the comparison shopping engines to know if they are up to the task of satisfying the needs of the e-consumer. This study adopts an exploratory approach about the history of online shopping engines, their operating modes, categories, and business plans as well as how they are perceived, used and evaluated. Then, a detailed identification of the various shortcomings that CSEs manifest on the side of both e-consumers and e-merchants was presented in order to eventually discuss the numerous innovations and scientific research which have been developed on the subject.

Keywords—Price comparators; shopbots; e-consumer; online consumption; shopping engines

I. Introduction

Consumers around the world are witnessing a rapid change with the increased digitization and globalization of markets [1]. Moreover, the emergence of new ways of communicating, electronic banking, e-purchasing and e-learning have changed most of economic interactions in the world [2]. This change, which increases both the number of choices and opportunities, intensifies the pressure on the consumer and promotes confusion in the world of digital consumption [3]. Today's online consumer is increasingly overwhelmed by offers that he is unable to evaluate [4].

In order to control damages, digital institutions with strong commercial influence have embarked on a search for an intelligent solution that will maintain the Internet user's uninterrupted contact with their products and promote their consumption. This solution should also reduce his confusion and feeling of overload by presenting him with the most suitable offer for his search. Thus, the comparison shopping engines (CSEs) appeared with the aim of assisting the consumer in his consumption process by easing his confusion through increasing the transparency and exhaustiveness of the service [5][6]. However, are they up to the expectations of the consumer? Do they meet his needs in respect of his believes and his the privacy of his virtual identity?

This article answers these questions and discusses their turnings according to the following structure: In the first section the article presents the concept of Comparison Shopping Engines (CSEs) and their different categories, the history of their creation, their Business Plan, their system of functioning as well as how to evaluate the relationship between a CSE and the online consumer. The second part was devoted to the presentation of an investigation the different disadvantages and limits of the current CSEs, either from the side of the consumer or that of the e-merchant. On the other hand, the third part was devoted to the elaboration of a discussion around the different scientific articles and innovations that have addressed this topic, whether with the vision of criticizing, improving or innovating in the field of comparison shopping agents.

II. Comparison Shopping Engines

A. Definition and Nomenclature

A comparison shopping engine (CSE) is an online service centralized in a website which, based on a request for a product or a service (bag, computer, washing machine, trip, hotel reservation...), will establish a list identifying certain factors of the product/service sold by several e-commerce platforms [7][8]. For each specific request, a list of offers collected from the e-commerce platforms surveyed is presented in price order according to the user's (decreasing or increasing) wishes[9]. In addition to the price, this list sometimes includes other specifications such as delivery details, payment methods and some technical information [10].

Comparison shopping engines (CSEs) have several nomenclatures, including:

- Shopbots, which is a term for the software agent on the main server of the comparison service [11].
- Price bots or "price comparison engines", which goes to the extent of allowing consumers to find the best price for a given product [12].

Or other designations such as: Price comparison websites, comparison shopping websites, e-commerce recommendation engines, etc.

B. History

The first shopping engines appeared in the mid-1990s [13][6]. BargainFinder was the first widely recognized product comparator, it was developed by a team led by Bruce Krulwich who worked for Andersen Consulting (now Accenture) in 1995

[7]. In 1995, BargainFinder was followed by the first price comparator, called Jango, created by the start-up Netbot, which was acquired by the Excite portal at the end of the same year [13]. Other start-ups were also interested in comparison shopping engines technology such as Jungle, which was acquired by Amazon.com, pricewatch.com, killerapp.com and NexTag which was nominated by Times Magazine World as one of the top 50 websites in 2008 [14]. Just after the economic crisis, like all global markets, comparison shopping engines found their way into emerging markets. With CompareXpress in Singapore in 2010, Baoxian (China), Jirnexu (Malaysia) and AskHanuman (Thailand) [10] whish, in 2013, increased its activity with solid investments in Big Data-oriented platforms, given the massive increase in data to be processed. Other price comparison websites such as FindTheBest, Priceza, Malaysia, Iprice and Save 22 have followed in the footsteps of AskHanuman in including this strategy.

C. Categories of Comparison Shopping Engines

The current CSEs are divided into multiple categories:

- General comparison sites: they are the most common on the web, generating a very wide spectrum of product categories (household appliances, entertainment, food, etc.) and services (insurance, travel, credit, etc.) [15].
- Specific comparison sites: these types of sites have come to specialize in particular areas to limit the plethora of online offers and be more exhaustive in their service. Example: travel comparators (Easyvoyages, Opodo, e-bookers,...), insurance comparators (Assurland, Kelassur, Le Lynx,...), etc. [15].
- Alternative Comparators: these are sites that allow you to find and rank a wide range of offers according to alternative criteria, such as geographical position or consumer opinions (Vozavi) [16].
- Hybrid comparators: these are sites that adopt a generalist approach while offering paid internal referencing services for merchants (Twenga) [17].

D. Business Plans of Comparison Shopping Engines

Regardless of the nature of the CSEs, they all generate their income based on one or more of these business models:

- Cost Per Action (CPA): This model is based on partnership agreements between CSEs and e-merchant websites to which they refer consumers. The referencing and ranking of e-merchant websites in a comparator are often managed in such a way that the latter yields a commission on each redirection or sale conducted through the comparison engine [15].
- The pay-per-click (PPC) or cost per click (CPC) system: each click by an Internet user towards an e-merchant website from a CSE provides the latter with an income of around 5 to 70 euro cents. CSEs generally propose to cap the monthly budget of their e-merchants. Thus, when the sum of clicks reaches the determined limit, the e-merchant's products no longer appear until the beginning of the following month [15].
- Fixed commercial agreements with associated e-merchant websites, which may take multiple forms such as "entry fees".
- Promotions and advertisements: Many comparators show ongoing promotions on displayed products or other products related to the research field [18].

The majority of CSEs generate their revenues on the basis of all the above mentioned. However, there is no doubt that there are those who, out of integrity, are solely satisfied with the revenues from the advertisements displayed on their pages [15].

E. How Price Comparators Work

The basic operating process of a comparison shopping engine includes the collection, storage, comparison and presentation of data. However, it is the data collection methods that distinguish most of the current CSEs. These can be roughly divided into four categories:

- Data Feeding: this method consists of the merchant website manager entering the initial information of the products and the catalog of the offers directly on the comparison website [13]. This method of supplying data essentially consists of allowing or encouraging online merchants to provide the data associated with the products they offer (the price or other specifications such as shipping costs, stock levels, discounts, etc.) in the specific data format defined by the CSEs. While allowing them to update their information as they see fit [13].

However, with the increasing number of comparison shopping websites and the excessive number of products to download, e-merchants feel bombarded by a huge amount of work, hence the need to use a specialized data flow management service has emerged. These needs have led to the creation of CSE data power management services such as SingleFeed [19] and FeedPerfect.

- Affiliate feeds: this technique consists of retrieving and directly filling in offer catalogs by connecting to e-merchant APIs [17][21]. This is achieved through downloading flows from their respective affiliate accounts to fill the catalog, display and update prices and information in real time. This method is considered the fastest but perhaps less accurate and, above all, less informative. Since only basic information is available via feeds such as title, URL, etc. [21].
- Data Wrapping: is a data recovery technique that can be performed automatically or manually to identify information contained in a web page and then transform it into a consistent format for further processing [13].

  It is a method of extracting the content from a particular information source and translating it into a relational form. Despite its slowness, due to the impossibility of exploring websites beyond a certain rate, it remains very rich and accurate. However, there are limitations that can be seen in the fact that many websites tend to set up Anti-Wrapping mechanisms to avoid being bombarded with too many requests [15].

- Data recovery from meta-engines: this technique is used by a new generation of price comparators which no longer base their searches on a selection of e-commerce websites but on the purchase comparators themselves by gathering information through queries from several price comparators and search engines [15].

Although data collection methods can be quite diverse, comparison methods to date remain largely based on the bid price factor, although the formula for exposing results may vary from one comparator to another depending on the display filters available, such as [15]:

- The relevance of the product to the user's request.
- The response time of online shops.
- The amount of information provided on the product.
- The number of sales made.
- Popularity (number of clicks by Internet users).
- The ranking filters chosen by Internet users [15].

F. The Relationship between the Internet user and the Comparison Shopping Engines (CSEs)

1) The consumer decision-making process and the use of the CSE: If we consider the classic model presented by Calin Gurau [13] on the decision-making process that a consumer maintains with a CSE, the latter uses the comparison shopping engine in three main cases, as illustrated in Fig. 1.

Another way of looking at things was presented by Guttman, Moukas and Maes in 1998 [22] that presents a somewhat different model from the previous one, which explains the six-step consumer-CSE contact process:

- Identification of needs;
- Product brokerage;
- Brokerage in e-merchants;
- Negotiation;
- Purchase and delivery;
- Service and evaluation [22].

Also, another vision of approaching the consumer decision-making process and the use of CSE has been studied by Rowley (200b) as shown in Fig. 2 [13]. However, although these processes are quite sequential and logical, they do not provide any indication of consumer attitudes/behavior during the research process [13] or of their satisfaction with the service provided.

2) The characteristics that determine a consumer's satisfaction with an online service: The evaluation of the elements influencing the feeling of satisfaction with the use of an online service was perceived in several ways. According to the SERVQUAL model, presented by Parasuraman, Zeithaml and Berry in 1988 [23], the quality of an online service can be determined according to the following characteristics: tangible assets, reliability, responsiveness, competence, courtesy, communication, credibility, security, accessibility, and customer understanding [23]. Then, using factorial analysis, these dimensions were reduced to five characteristics: tangible assets, reliability, responsiveness, assurance and empathy [23].

However, given the speed of digital transformations and the enormous growth of online services, these characteristics have required significant adaptation. Zeithaml, Parasuraman, and Malhotra, therefore, identified in 2002 an improved set of the above-mentioned characteristics [24]: reliability, responsibility, accessibility, flexibility, ease of navigation, efficiency, assurance/trust, security, price-knowledge, site aesthetics and personalization, developing on their basis an e-SERVQUAL model [24].

However, these features may apply primarily to retail websites, which are more or less more complex than current price comparators.

3) The characteristics determining a consumer's satisfaction with the quality of a CSE: A study also conducted by Calin Gurau [13], aimed at defining the determining characteristics of the quality of a CSE for a consumer. The study was based on a set of interviews conducted with 121 respondents who indicated the characteristics that define the quality of a CSE for them [13].

At first, 81% of respondents considered the ability of the CSE to find a lower price offer to be a very important criterion [13]. Second, 80.2% of respondents highlighted ease of interaction as an important aspect of their contact with a CSE [13], knowing that this criterion was presented to them under several characteristics including reliability, functionality, ease of navigation, clarity of the various information/indications and the available tools (search, selection in a list, order of results according to various headings …) of the comparison website [13]. In third place, the accuracy of the comparator in finding the right desired offer is considered important by 76.8% of respondents [13]. Followed by 70.2% of respondents who say that the desire to have additional information about the offer and/or the supplier is important to them [13]. Finally, 58.7% of respondents like CSEs which, in addition to online offers, also provide access to the ratings, comments, and evaluations provided by former consumers [13].

In addition, Calin Gurau [13] interprets these results in a different way when she considers the existence of a good dependency relationship between these characteristics. Thus it states that as the price level becomes average and low, the need for additional information becomes less important. On a side note, the proportion of people who indicated the importance of ease of interaction remains quite indifferent to price [13].

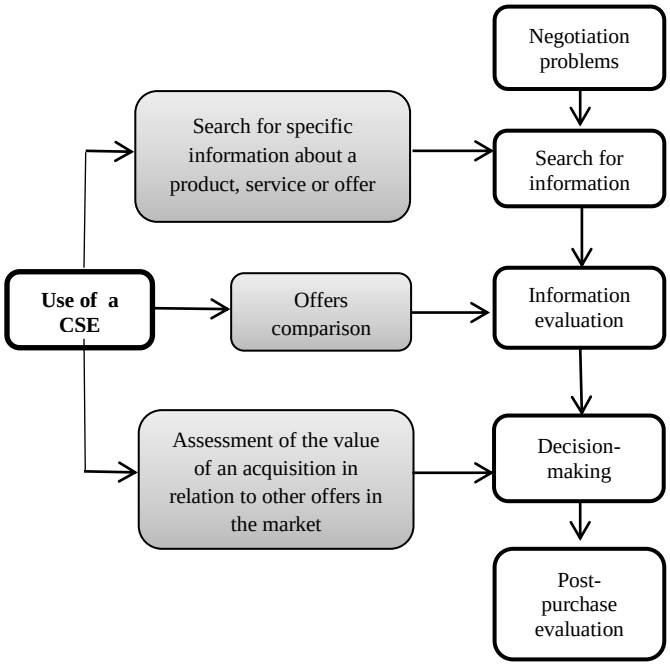

Fig. 1. The Consumer Decision-Making Process and the use of the CSE [13].

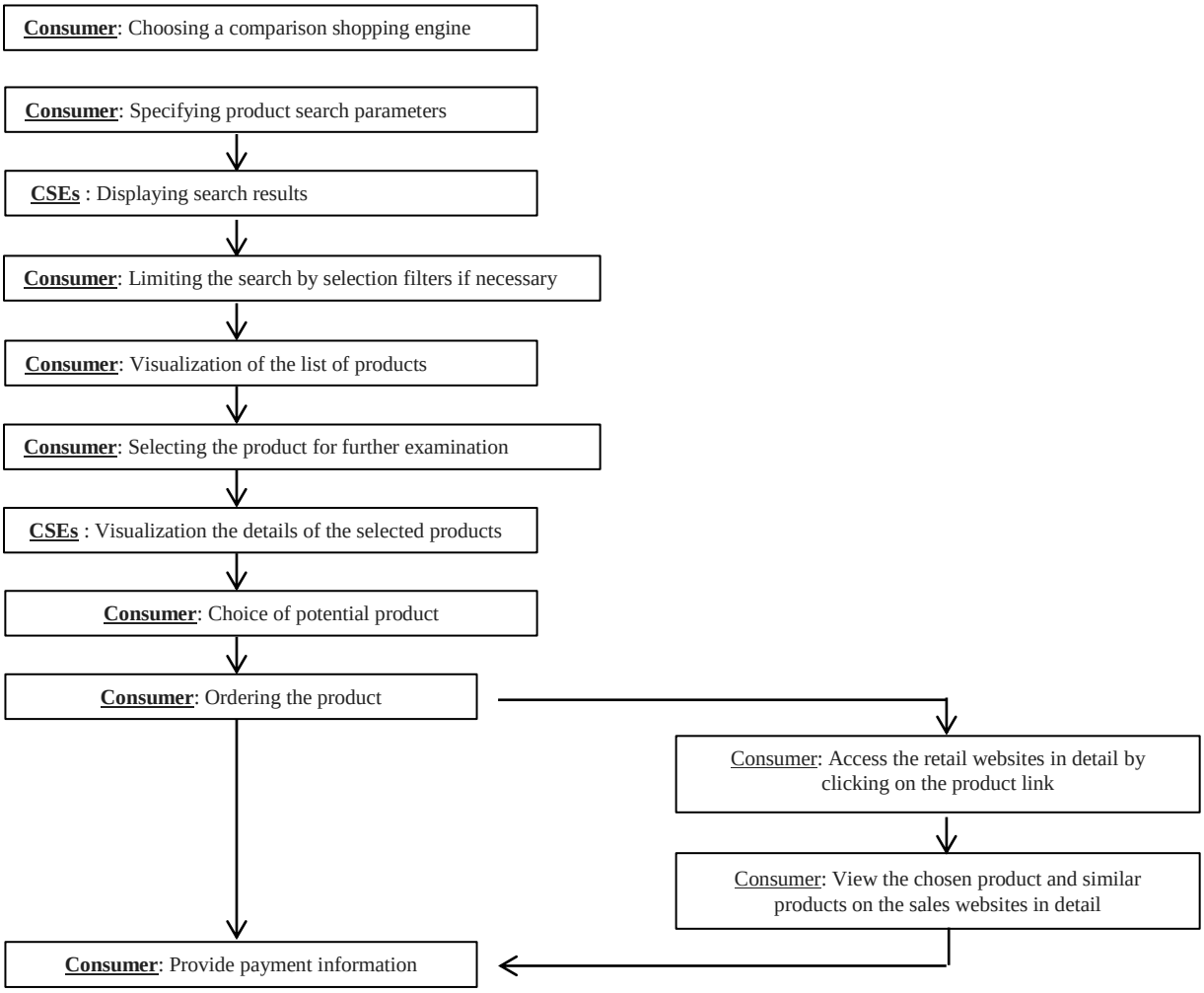

Fig. 2. The Process of Searching and Acquiring a Product using CSEs [13].

III. Shortcomings of the Comparison Shopping Engines

Despite the important change that the comparison shopping engines have made, whether for the benefit of e-merchant websites or for the benefit of e-consumers, and although they have significantly improved in recent years, they still present some limits that must not be omitted in order to adapt to an e-consumer increasingly informed, curious and driven towards the notion of a good deal.

A. Shortcomings Affecting the E-consumer

The relevance of the price comparators and their benefits for the e-consumer are undeniable. Based on the valuation of the least expensive price, CSEs create competition between e-merchants which reduces the price to the benefit of the e-consumer [25] [26]. Moreover, it reduces the time the consumer spends searching for a product [11] [27] [28]. However, all these advantages remain insufficient considering that all the factors induced by the new era of marketing and digital transformations encourage the CSEs to review their approach [29]. Among the CSEs shortcomings considered significant are those presented in Fig. 3.

1) Insufficient functionality and adaptability

a) Inadaptability of results: This limitation is explained by the absence of the consideration of certain characteristics of the product desired by the consumer in the search and/or the comparison of offers; the thing that gives results that are not totally adapted to the need of the e-consumer. A customer already overwhelmed by all online offers and advertisements [3], or looking for particular criteria, finds himself unsatisfied and unable to decide, faced with a list of offers whose only criterion often valued during the comparison is: the price, especially since the variation in prices between e-merchants is mostly insignificant [11]. Thus, he feels obliged to go and do the work of comparing the other criteria himself in order to make a good decision.

b) Non-exhaustiveness of results: While the consumer uses a CSE to carry out on his behalf a general search of existing offers on the web for a product he wants, he finds himself presented with a small pre-prepared list following commercial arrangements between CSEs and e-merchants [30][28]. A study carried out by the DGCRF (General Directorate for Competition Policy, Consumer Affairs and Fraud Control) reveals that the majority of CSEs do not relay all the offers in a sector, but only those of partner merchant website. Thus, the informed consumer has the feeling that he is being manipulated by the omission of other offers that may be more interesting for him. This can damage completely the reputation of the comparator.

2) Lack of transparency

a) The omission of certain information by CSEs: The majority of price comparators choose to omit certain specifications while offering their price comparison, such as the price in VAT or the delivery price, which may be higher than the price of the product in some cases [13]. This completely distorts the relevance of the classification, causing it to lose the consumer's trust.

b) The non-ethical arrangements between the CSEs and the e-merchants: Most of the comparators base their offers' comparison on arrangements made with e-merchants[30]. Thus, in their ranking, some choices are more visible or better ranked than others, which can distort the e-consumer's judgment [30]. As a result, and following the complaint of certain consumers, who require comparison sites to provide impartial information [31], and the recommendations made by the DGCCRF (General Directorate for Competition Policy, Consumer Affairs and Fraud Control), a code of ethics for comparators was adopted on 11 June 2008, giving rise to the label "comparator charter" [31] , whose signatories undertake to:

- Be more transparent about the prices displayed (including VAT, delivery costs) and the criteria that govern the classification of offers.
- Specify the non-exhaustiveness of the search results.
- Refresh the processed data at least every 24 or 18 hours [31].

3) The lack of consideration of consumer preferences in the evaluation of offers: Besides, the criteria attached to the offer (product/service specifications, the offer bonuses, price, etc.) or those specific to the consumer's profile (age, gender, etc.) that some CSEs take into consideration when collecting offers, there are other criteria that are as important to consider in the collection and evaluation of offers. These criteria are mainly based on preferences that deeply affect the health of the consumer and his consumption believes [32].

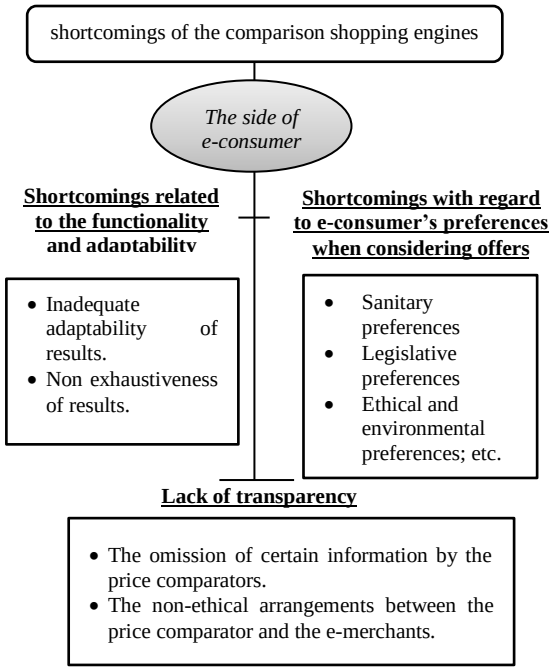

Fig. 3. Shortcomings of the Comparison Shopping Engines: the e-Consumer's Side.

a) Health preferences: Several products with strong allergenic substances or totally defective substances are put on sale on the online market (drugs, food supplements, food products, hygiene products, cosmetics, Ayurveda products, etc.) [33]. For instance, multiple allergies, intoxications and dangerous diseases are caused either by the allergenic substances in food products, the increasing complexity of the food chain, the emergence of biotechnologies and the emergence of new products *with poorly controlled consequences either in their* content (genetically modified organisms, use of dangerous dyestuffs: E102, E110, etc. [34], use of heavy metals [35]), or in their packaging (use of nanotechnologies in packaging to increase shelf life) [36]. Thus, the consideration of these factors, whether in the evaluation of the offer or in raising the awareness of the e-consumer prior to purchasing the product in a transparent, efficient and understandable manner, remains essential, increases purchases [37] and creates a relationship of loyalty and trust [34].

In the cosmetic field some websites offers exclusively a service that considers the consumer's health preferences, such as INCI Beauty[38], QuelCosmetic [39], etc. However, it still has a limited existence on the web in general, endangering the health of many consumers who lack the knowledge or time to do all the necessary research by themselves.

b) Moral and legislative preferences: The lack of consideration of legislative standards and risks may manifest itself in the absence of rising the consumer's awareness or warning him of the laws of the country of destination, related to the consumption or order of a product especially those that are suspicious (contraband products [40], counterfeit products [41], stolen products, expired products, toxic products, etc.) and/or the authorized quantity of the latter. Because, this could cause several problems for the consumer, such as the loss of money in the confiscation of the product by customs, very high customs fees as well as penalties, and even jail time [42].

In line with current marketing trends focused on rising the customer's awareness, a consumer should be notified of the legal risks, customs measures and any other possible risks (diseases, allergies, etc.) for any product before ordering it, so that he can make a responsible decision.

c) Ethical and environmental preferences: The current consumer is becoming increasingly educated and involved in the manufacturing process of his products [43]; however, this is not well taken into account by CSEs. For example, in the case of customers who are sensitive to products tested on animals or manufactured in conditions (child labor, etc.) that do not respect employment rights etc., they are dissatisfied with a comparison that does not include a valuation of their consumption principles and which eventually obliges them to search for themselves behind each proposed offer to position it and to be able to take the right decision [44].

B. Deficiencies Affecting the E-merchant

E-merchants benefit greatly from the services offered by CSEs. Indeed, having their product catalog displayed in these comparators is a way for them to obtain good visibility, qualified traffic, a way to reach potential customers directly during the purchasing phase and to benefit from a good competitive intelligence tool [25]. However, this does not remain without disadvantages, because some e-merchants feel that they are serving as a decoy by inflating the comparator's list of results, giving them credibility in the process, and allowing their competitors to distinguish themselves. Among the shortcomings suffered by e-merchants are those presented in the diagram in Fig. 4.

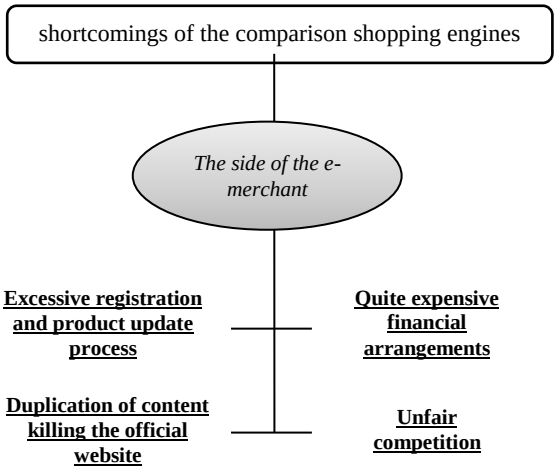

Fig. 4. The Shortcomings of the CSEs: E-merchant End.

1) Quite expensive financial arrangements: It is not easy to be part of the top lists of comparison shopping engines. First, there are often fairly expensive financial arrangements in order to be frequently recommended or well ranked in the list of recommendations [30]. These arrangements can be manifested in different packs as explained earlier: cost-per-action (CPA), cost-per-click (CPC), referencing, registration and handling fees, subscription, etc. [31] which may represent a big burden for e-merchants in startups, unable to invest so much money in communication.

2) Unfair competition: In the case of the majority of CSEs, the e-merchant capable of paying more will be the most recommended[11]. This rule is discouraging to other growing e-merchants because, despite the quality of their offers, they will remain in the shadow of large websites able to pay the price necessary to have the greatest traffic and the best visibility.

3) The overly cumbersome registration & product update process: When the updating of the products on the CSE is done manually, it requires a lot of investment in terms of effort, time and even money, once delegated to a service provider.

4) Duplication of content can harm official site traffic: The value of an online store lies in the richness of its content. An e-merchant administrator duplicates the content of his official website on the CSE when he puts the products under the same name, description, photo, etc. Thus, depending on how Google works, it will consider that there is no use of displaying all these multiple websites with the same content

and will choose the one with the greatest traffic that it considers most reliable to place on first pages while the others will be put, including the official website, in the outskirts of the web (relegated to the 10th page or beyond) [45]. Therefore, for the e-merchant to be able to fight against this form of cannibalization, it will be necessary to provide the means to differentiate the content of the official site with each CSEs. This can be costly and time-consuming and must be done by highly skilled people to differentiate the content offered without altering the nature of the offer.

IV. Discussion of New Innovations and Aspirations for the Future

A. State of the Art on the different Scientific Innovations around the CSEs

In the face of the aforementioned shortcomings of the comparison shopping engines, recognizing the limits of a solution and the causes of its dysfunction is not enough, it is also necessary to seek to improve it or find possible alternatives.

With this in mind, the article discusses some of the work that has been done in this area.

In a 1998 study entitled "Agent-mediated Integrative Negotiation for Retail Electronic Commerce" [46], the challenge was to generate a list of products that were functional and adapted to consumer criteria without being limited to the price factor alone. This work focused on generating customized lists of product and e-merchant information associated with the corresponding specifications (prices, etc.) and incentives (extended warranty, delivery time, etc.). The thing that is currently being done partially in the CSEs. Thus, it was based on multiple attribute utility theory (MAUT)[47], which is founded on two distinct analyses: the first is uncertainty, which covers the consideration of certain uncertainty on the consumer side for situations such as "how much should I trust this merchant?" and on the e-merchant side for others such as "what will be the demand for this product?", thus it addresses the uncertainties of attribute values in purchasing decisions in relation to customers and bid decisions in relation to e-merchants. The second analysis is the utility analysis, or in this case, the preference, which analyzed multiple attribute preferences[46]. Inasmuch as these analyses have had acceptable results they have not been able to adapt over time to the satisfaction of the functionality, adaptability, and customization of the products offered at the request of the consumer. To which the approach of this work required direct feedback for the acquisition of uncertainties and utilities before the application of their MAUT theory for the generation of the customized ranked list. This represented a burden for consumers who should be involved in collecting uncertainties [32].

In addition, another research project focused on this vision in 2002. Soe Tyran in her article "A personalized and integrative comparison-shopping engine and its applications" [32] raised the question of considering the existing differences between e-consumers and also those of e-merchants in the comparison of offers while disapproving the comparators limited only to price. In her article she proposes a solution that she called "personalized sales agents and integrators", the latter can be summarized as a comparison engine that includes both a "product / merchant information collector" and a "behaviour extractor" that acquires consumers' behaviour towards products (the time spent by the consumer browsing the details of articles, surfing the online store, the websites that the consumer browses), A "user profile manager" that keeps track of the most common consumer behaviors and behavioral analysis results generated by "the personalized online ranking module" that covers the agent-activated behavioral analysis of interactions (With consumer behavior history and product/merchant information, the module does the necessary reasoning / calculation / analysis of multiple product/merchant terms to provide a better personalized ranking. Where the favorite objects are placed first) [32].

In her work, Soe Tyrant used the interactive power of the Web to analyze user behavior to capture dynamic consumer preferences over time, whereas for ranking, she used learning by reinforcing time differences with the approximation of value. With the aim of finding the list of products / e-merchants classified in order of importance, where the position of the products in the classification is proportional to the interests of the consumer [32].

In another case, in 2010, research again focused on this theme but remained limited, once again, to the price factor. In an article entitled: "A comparison shopping optimization model based on suppliers' pricing contexts" [48], Yong Sik Chang and Kyoung Jun Lee wanted to emphasize the importance of taking into account the supplier's pricing strategy in the comparison. Thus, they proposed a comparative shopping optimization model based on supplier price contexts that offers, to online consumers, suppliers sorted by effective and realistic prices. This is interesting, but not very comprehensive given the vision undertaken by the previous articles. [48].

Just after, in 2011, another research project focused on the shopbots, but from a completely different angle, not covering the comparative assistance of the filters associated with the e-customer/e-merchant. But rather, globalizing research and allowing access to all the world's products. The article "Designing a cross-language comparison-shopping agent" [49] came with the proposal of a shopbot called "WebShopper" to help customers find and compare e-merchants who market their products using different languages, which can be interesting since the majority of suppliers offer international delivery, this shopbot is built with a multilingual ontology based on a semi-automatic method using formal conceptual analysis and association analysis [49]. It also generates an automatic method for categorizing product data into predefined classes, in order to reduce the workload of administrators. In addition, a semantic search mechanism based on concept similarity is designed to help customers find more desirable products which can prove to be very interesting [49].

Returning to the comparison based exclusively on the price factor. Another article, in 2015, entitled "Improving comparison shopping agents' competence through selective price disclosure" [50], asks questions about the most effective

way to present the prize in order to attract the Internet user's attention and increase the chance of their consumption. Thus, it proposed a new approach, called "selective price disclosure", based on the removal of certain product prices from the list presented in order to affect the buyer's beliefs as to the possibility of obtaining more attractive prices. In this context, two methods were proposed. According to the article they are adapted to fully rational buyers to decide which of the prices known by the shopbot should be revealed [50].

B. Innovations Implemented by E-commerce Leaders

Nowadays, the web is becoming more and more a fertile ground for price comparators. From the moment they realized the profits that could be generated from CSEs, either in advertising, in partnership and especially in collecting consumer data, the majority of digital institutions with strong commercial influence on the net have invested in it. Among the most famous shopping comparison engines in the e-commerce field today, we can mention Google Shopping, NextTag, Price Grabber, Shopping.com and Shopzilla, etc. [13] [51].

The majority of these comparison engines use the price criterion as the sole factor for comparing offers [32]. With the exception of Google shopping, which despite its price valuation, tries to introduce other criteria to improve the quality of its services [17].

1) Google shopping: Google Shopping is a tool to promote an e-merchant's products on the Google network and its partners.

In order to start selling on Google Shopping, it is necessary for an e-merchant to communicate the nature of his product catalog available to Google via Merchant Center (GMC), an interface to configure his data flows to Google Shopping servers as shown in Fig. 5, and as previously explained in the CSE operating system [17].

Fig. 5. Google Shopping Operating Process [17].

In turn, Google Shopping feeds comply with certain rules relating to their analysis and verification of offers in order to ensure the quality of the service promised to the consumer, among the rules taken into consideration we find some of them to be related to:

- The legal framework, such as: copyright, counterfeiting law, linguistic, and sexual safety.
- Brand communication (sensitive subject, inciting hatred).
- Transparency (affiliation, misleading representation, bundled offers, etc.).
- To the management of the GMC account, etc. [17].

2) Price Grabber : PriceGrabber.com [52] is a commercial price comparison and distributed content trading website founded in 1999 by former CEO Kamran Pourzanjani and Tamim Mourad[53]. The company works with merchants, retailers, and vendors to provide information on a wide range of products [54].

PriceGrabber is similar in its operation to the majority of CSEs. However, it was the first comparison engine to project information on taxes and shipping costs for a consumer during the price comparison process [13].

V. Analysis and Deductions

After a bibliographical study around the comparison shopping engines and the scientific innovations, the research proves that although the offer ranking formula varies from one comparator to another, the comparison of these offers is generally established by considering the price of the products as the major factor.

So, as it can be clear to us that, despite all the transformations in digital marketing and the great centralization on the customer. Scientific research and dominant price comparators [32] [55] have not yet been completely involved and continue to be restricted to the valuation of the price factor without considering all the aspects that are of greater importance to the respect of customer rights and preferences.

VI. Conclusion and Outlook

Following the problems generated by the excessive overload of the Internet user with online sales offers. The consumer is relieved to turn to comparison shopping engines to save time and energy.

In order to measure consumer satisfaction with this service, this article focused on carrying out an investigation into the comparison shopping engines. The investigation proved interesting in that several shortcomings and limitations were revealed in the quality of the services provided to e-consumers, which is still particularly dissatisfied with the lack of integration of several criteria in addition to the price in the evaluation and comparison of offers.

Thus, despite the growing importance of CSEs for the development of online consumer markets and transactions [25], the leaders of current CSEs and the existing scientific

innovations have not yet taken into account in the CSE's comparison and evaluation process the consumption characteristics suited to the consumer's personal profile and consumption behavior.

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Classifying Red and Healthy Eyes using Deep Learning

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***Abstract*—Eye is one of the most vital organs of human body. Despite being small in size, humans cannot see the life around them without it. Human eye is protected by a thin covering termed as conjunctiva which protects the eye from dust particles. It plays the role of lubricant in the eye which prevents any sort of friction in opening and closing of eye. Broadly there are two kinds of conjunctiva: bulbar and palpebral. The membrane covering the inner portion of eyelids is termed as palpebral conjunctiva and the one covering the outside portion of the eye is called as bulbar conjunctiva (white portion of eye).Due to the dilation of blood vessels the white portion of the eye also termed as sclera becomes red in color. This condition is also termed as hyperemia. The study of this development is vital in diagnosis of various pathologies. It could be result of some trauma, injury or other eye related diseases which needs to be identified for timely treatment. Enormous amount of studies have been done to study the structure and functionality of human eye. This paper highlights the work done so far for measuring the level of redness in the eye using various methodologies ranging from statistical ways to machine learning techniques and proposes a methodology using Matlab and Convolutional neural network to automate this evaluation process.**

***Keywords*—Bulbar conjunctiva; hyperemia; convolutional neural network**

I. Introduction

Conjunctival Hyperemia results due to the engorgement of blood vessel in the sclera of the eye. Due to this there is accumulation of blood in the vessels which makes them thicker in size in terms of width. The severe the injury, the more engorgement it results into. As the circumference of the blood vessels gets increased, it results into redness of the affected area. Depending upon how serious the trauma is the level of redness varies. It could range from slight red to severe red. Scholars have worked out various ways of measuring the degree of redness. An effective methodology to measure this is important for diagnosis of various other eye related pathologies. The most important factors that help clinicians to classify hyperemia are degree of redness, hue of the colour and location of the vasodilation [1]. The accurate interpretation of bulbar redness can identify various pathologies like morning eye congestion, bacterial conjunctivitis, dry eye [2], trauma due to prolonged use of contact lenses, iritis and other severe infections [1][3]. It is also a well know side effect of glaucoma treatment [4].Because of these symptoms, patients suffering from the glaucoma drugs often discontinue the treatment [5].Timely and correct diagnosis of these conditions can further reduce any damage to the eye and also help in treatment plan. From last two decades researchers have been working to scale the redness level of the eye in the best possible ways. Most of the work is focussed on subjective analysis of bulbar conjunctivitis using methodologies that involved verbal classifications of redness and/or through pictorial representation. Later the concept of image processing was used extensively to remove the subjective dependency in scaling the redness and various automated approach were presented. This study presents the journey of scaling the hyperemia from manual approach to automated approach by various scholars. The objective of this paper is to analyse the work done so far in the clinical assessment of redness. The paper is organised into various sections: Section II briefly highlights the subjective assessment of hyperemia. In Section III detail research in objectively scaling the hyperemia is mentioned. Section IV highlights potential new way of assessing the redness. Results and conclusion are presented in Sections V and VI.

II. Subjective Assessment of Hyperemia

Ocular surface assessment is a routine procedure and one of the common methods to do it is subjective observation and description [6]. Assessment of bulbar redness is quite difficult owing to the contrast of repeat assessment among different clinicians over a period of time [7] [8] [9]. Also various internal and external factors make the subjective analysis much unreliable and results varies from observer to observer [10]. Clinical grading can be performed using at least two general approaches. One that involves the brightness of the eye and other that is based on the various features of the vessels of the concerned area. [8] Paul highlighted the features like vessel tortuosity, number of vessels in the area of study and the diameter of the blood vessels to measure bulbar redness. The clinical assessment of bulbar conjunctivitis is subjective in nature [11] and is poorly understood. It is primarily based on grading scales. The challenge in grading is that the grades themselves are poorly described and moreover due to the varying learning abilities, it is not clear how clinicians grade the redness [10] [12]. The early scale developed was photography based McMonnies/Chapman-Davies scale, which graded conjunctival hyperemia on six levels. [13] It was quite useful for clinical application but was restricted to contact lens wearers. The scale established that hyperemia in soft lens wearer is relatively high as compared to hard lens wearer. Further CCLRU standards (cornea and contact lens research unit), which was earlier termed as IER scale (the Institute for Eye Research scale) was developed [14]. This scale highlighted the clinical performance of lenses with respect to short and prolonged use [15] [16]. It graded the bulbar redness on a 5-point photographic scale where 1 stands for very slight, 2 means slight, 3 signifies moderate and 4 represents the condition as severe. The results of this scale lacked in homogeneity, either in terms of different

illumination conditions or variability of size of the area under display.Later Efron grading scale was developed which graded the severity of hyperemia on the scale of 0 to 4 [17]. But it again was limited for contact lens complications and images taken into consideration were rendered by an artist to highlight severe condition. Moreover it was not efficient in providing a continuous linear quantitative evaluation.

TABLE. I. COMPARATIVE ANALYSIS OF SCALES USED FOR EVALUATION OF BULBAR REDNESS

Scales	**Grading Levels Used**	**Application**	**Limitation**	**Interpolated grades**	
McMonnies/Chapman-Davies scale	Graded conjunctival hyperemia on six levels	Useful for clinical applications. It also showed high degree of inter-intra observer reliability	Restricted only to contact lens wearer	**VBR**	**MCD**
				0	-
				10	-
				20	1
				30	2
				40	2.8
				50	4
				60	4.8
				70	>5
				80	>5
				90	>5
				100	>5
Brien Holden Vision Institutescales (CCLRU)	Graded conjunctival hyperemia on 5-point photographic scale	Helps in describing the severity of 6 contact lens complications	Unable to depict homogeneity between different images of same conditions.	**VBR**	**CCLRU/IER**
				0	<1
				10	2.1
				20	2.4
				30	2.8
				40	3.6
				50	>4
				60	>4
				70	>4
				80	>4
				90	>4
				100	>4
Efron	Graded conjunctival hyperemia on the scale of 0 to 4. It use painted/artist illustrated images	Helps in describing the severity of 16 contact lens complications	Didn't provide efficient continuous linear quantitative evaluative	**VBR**	**EFRON**
				0	-
				10	0.3
				20	1
				30	1.5
				40	2
				50	2.3
				60	2.6
				70	3
				80	3.5
				90	>4
				100	>4
Validated bulbar redness scale	The position of image was recorded on a range of 0-100 scale	Incorporated the relevance of combining psychophysical and physical attributes of a scale	Limitation in evaluating digital images in terms of ease of use , reproducibility		

Later validated bulbar redness scale was developed which mentioned the importance and relevance of combining psychophysical and physical attributes of a scale [18]. Range of 0-100 is being used in this scale and it is currently available in two versions. VBR [5] and VBR [10], [19] Schulze further deployed cross-calibrated reference grades which helped in comparison of various already established grades. It proved that estimates of redness were higher on scales with shorter range. These studies covered and detected small changes in hyperemia in the affected region and also some of them were conducted on lens wearers. Bulbar redness is in some cases unevenly distributed, so it requires a methodology which can cover the entire ROI (region of interest) and generate reproducible results with automated approach. Table I summarizes the details of all the grades being used by observers to grade bulbar redness. It also shows the conversion chart of these interpolated grade developed by [20]. The table clearly indicates that no specific scale can be regarded as best or least.

III. OBJECTIVE ASSESSMENT OF HYPEREMIA

Looking at the limitation of subjective assessment and its drawbacks in producing varying results, made the scholars work towards finding an objective, continuous and automated way of assessing bulbar redness. Image processing and analysis have been explored by scholars from last two decades to avoid the dependency on subjective grading of hyperemia. With the evolution of computer and sophisticated softwares, this approach of automation gained prominence. Initial study [21] in this area resulted in a semi-automated approach which showed that a variation of only 5% was there when the same portion of the same eye was analyzed at different times. Also it resulted in less than 0.02% variation of the same negative when subjected to repeated analysis. Later in [22] an algorithm was proposed which performed computer based image analysis using image smoothing and edge detection methods. It could grade minor to moderate degree of hyperemia and showed a correlation coefficient of 0.6. But the photographs with poor sharpness were not well suited for this analysis. Further an automated approach based on image analysis was proposed which took into consideration mean relative redness and blood vessel area ratio of the affected eye [23]. It reduced the dependence on operator but incurred costs in terms of hardware and software.Some proposed techniques later could differentiate slight change in diurnal cycle [24]. Some but not all methods demonstrated high level of correlation with subjective gradings [25]. Also the work took into consideration relatively smaller patch and therefore was different from clinical grading as in clinical grading both nasal as well as temporal area are considered. In [26] an automated estimator was developed for conjunctival hyperemia using multivariate regression technique. The correlation coefficients for nasal side were 0.98 and for temporal side was 0.96. But the study took into consideration very less features. Later [27] proposed an estimator which established the relationship between clinical grading and quantitative aspects of conjunctiva images. The study focussed on elimination of irreproducibility and inconsistency of the clinical ratings in order to get accurate and consistent results. Though the proposed estimator reliably predicted median clinical grades

but the results were not linear for higher grades of bulbar redness. Another study [28] proposed the use of image analysis to quantify changes in hyperemia. Techniques like color extraction, edge detection and thresholding were used to have a higher level of repeatability. In [29] another objective method was performed to measure bulbar redness using Spectrascan650 Photometer by Photo Research. This study drew comparisons between objectively measuring hyperemia through photometric method with standard grading techniques. Further [30] establishedobjective grading methods which were sensitive and more reliable in detecting and monitoring ocular surface changes. Regression analysis was used to establish correlation between subjective grades and objective measures.

Later in [31] scientists looking into the tedious and time consuming job of grading hyperemia, proposed an automatic approach for selection of best frame for grading. The results of this automatic approach were repeatable, objective and less time consuming. The frames were selected by taking into consideration features like lightness, non-blurriness, or high contrast.This work was further extended in [32] where concept of artificial neural network was incorporated to grade bulbar redness. The proposed methodology transformed the extracted features into grading scales using radial basis function network [33] and multi-layer perceptron [34]. This study implemented extraction of region of interest from best frame. Later various features were computed from region of interest. Lastly artificial neural network was used to transform these features to specialists grading scales. The study however consideredlimited set of features for evaluation. In [35] machine learning techniques like regression and classification were used and their results were compared in grading the red eye. In another study [36] focus was on considering image processing by implementing image segmentation in the evaluation of redness.

Though the objective assessment of bulbar redness has proved to be less time consuming by reducing the involvement of clinical judgement. Still there is a constant need of features extraction involved, which are further transformed into the grading scales. The objectivity thus still is biased on the features selected. The study presented in this paper automatized the entire process of differentiating healthy eye from red eye by extracting the color intensity from the eye and feeding this extracted image to convolution neural network.

IV. Methodology

A. Data Collection

Twenty eight images of bulbar redness were used and twenty eight images of healthy eyes were used. The images were captured throughthree step slit lamp model number HUVITZ 500N using CANON EOS 1300Dcamera attached to it by vision centre of school of health sciences. The images were imported through the software HIS500N (HUVITZ imaging slit lamp).

B. Color Extraction from Input Image using MATLAB

The coloured images of red and healthy eyes were acquired from vision centre. The images were then read through imread () function [37] of MATLAB. The function returns the input image in the form of array. The color image is returned in the form of three dimensional matrix. After application of various functions of MATLAB, the white color from these input images was extracted using the image processing toolkit of MATLAB.

Algorithm for colour extraction from images

1. Read an input image
2. Display the original image
3. Extract the individual red, green and blue color channels
4. Define a threshold value of 200
5. Generate a binary image where each color channel extracted above is more than the threshold value
6. Binary image showing white portion is now extracted
7. Display the binary image
8. Stop

Initial requirement of image processing task is to have a coloured image referred to as RGB image. The RGB format of the image is stored as m*n*3 matrix that defines red, green and blue color component for each pixel. The red, green and blue color channels are extracted from the original image. They are stored as three independent two dimensional matrix for each color channel. Further a threshold value is defined to extract the white portion from all these three two dimensional matrix. The binary image [38] [39] [40] is finally generated where each color channel has value greater than the threshold value. Fig. 1 shows the extracted white portion of the healthy eye.

Fig. 2 shows that in case of severe red eye there is minimal white portion.

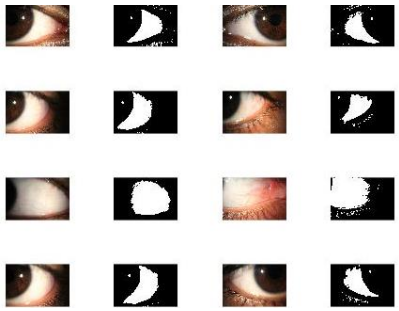


Fig. 1. Extraction of White Color from Healthy Eye.

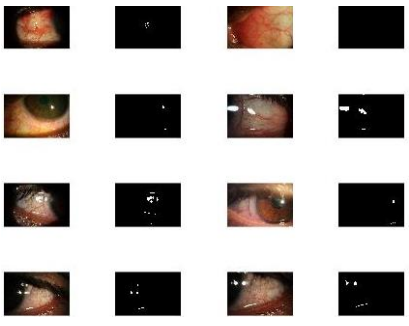


Fig. 2. Extraction of White Color from Red Eye.

C. Binary Images fed to Convolutional Neural Network

1) Convolutional neural network: Convolutional neural network is a special kind of neural network which can work on images ranging from one dimensional, two dimensional to three dimensional. Simple neural network doesn't stand good on feature extraction and feature learning. On the hand CNN works efficiently on excellent feature extraction and learning. The advantage of ConvNet over regular neural network is that it considers every input as image. This consideration helps in creating the architecture in much better way. The neurons of the CNN are arranged in three dimensions w*h*d, where w is the width, h is the height and d is the depth. For an RGB image depth is 3. Each corresponding to red, green and blue color channel.The Convolutional neural network consist of the three main layers. [41] Convolutional layer, pooling layer and fully connected layer. The Convolutional layer is the core of the network that does maximum of the work [42]. The purpose of this layer is to extract high level features from the input image, this is achieved by striding the filter/ kernel over the input image. A kernel is a matrix whose size depends upon the input image being processed. If the image is having multiple channels then the depth of the kernel is same as that of the input image. Convolutional layer doesn't restrict to only one, the network can have many convolutional layer as per need. Further ReLU (rectified linear unit) is applied to the output of convolved layer. Its main purpose is to minimize the computation time [43]. Similar to the convolutional layer the pooling layer main task is to reduce the size of the convolved image. The most popular being the max pooling method [44]. It helps in extracting the dominant features by selecting the maximum value from the portion of image covered by kernel. At the end the output is flattened and fed to the fee forward neural network and backpropagation is applied. After number of iteration the model is able to classify the features.

2) CNN based classifier: We have now a self-curated dataset consisting of extracted "white" portions from human eyes. The goal of this classifier is to classify input image of human eye in two categories, i.e. "Red" or "Healthy". The proposed model start-off by splitting the dataset into training set (75%) and testing set (25%), followed by augmenting the images in the training set. The image augmentation techniques included rotation, width shifting, height shifting, shear transformation, zoom, and horizontal flipping [45]. The whole dataset was normalized, and the images were resized to a size of 28 x 28. For the purpose of training a model, we used Convolutional Neural Networks. A convolutional neural network learns Spatial Dependencies for the representation of images. The convolutional layer makes use of filters, also known as kernels, to form a matrix by sliding the filter over the input image and computing the dot product. This matrix is called a "Convolved Feature Map" or simply "Feature Map". The feature map is directly influenced by Pooling and Strides. Pooling progressively reduces the spatial size of input images. This further reduces the amount of computations. We make use of Max Pooling in the training of our model. Secondly, Stride refers to the number of pixel shifts that a kernel is supposed to make while extracting features from the image representation. Moving on to the architecture, a Sequential neural network was developed that consisted of the following layers:

- Convolution2D layer with a number of 20 output filters, kernel size of 5 x 5, zero padding and input shape of 3 x 28 x 28
- Activation layer of ReLu – Rectified Linear Unit
- Max Pooling layer with a pool size of 2 x 2, and (2 x 2) strides
- The above orientation was repeated again but now with a number of 50 output filters in convolution2D layer.
- Flatten-The output from second pooling layer is flattened into a 1D array
- A fully connected layer consisting of 500 nodes.
- Another ReLu activation layer
- Finally, the output layer consisting of a single node with Softmax activation function.

The dataset was trained for 100 epochs with a batch size of 32. The model was compiled using "Adam" optimizer [46] [47] with an initial learning rate of 0.001, further decaying at the rate of 1e-5. The results were quite satisfying. After a total of 100 epochs, we got a training accuracy of 96.88%, with a loss of 11.9%. The validation accuracy had reached 93.33% with a validation loss of 21.83%. As can be seen, our convolutional neural network performed really well in classifying human eyes as healthy and infected (Red). We propose this model for the noble cause, so that no patient with healthy eyes is to undergo the time-consuming check-up procedure.

V. Results

Table II shows test results of the model for healthy eyes. The result includes an input image which was generated after extracting the white portion of the original healthy eye. The output includes the labelled results along with accuracy which we got after feeding the extracted image to our proposed CNN based model. It clearly shows that our model is able to classify well healthy test images passed to as healthy.

Table III shows the output of the model for red eyes. The result includes an input image as test image without label. The output is the correct prediction of the model for red eye with high accuracy. The output images are generated with label as red.

For testing the accuracy of the model a set of 15 images of red as well as healthy eyes each were passed to the model without labels. The model predicted well in both the cases along with labels as red or healthy.

The output accuracy of Table II and Table III are collated in Fig. 3. The figure shows the average accuracy of classifying healthy and red eyes. The chart shows an average accuracy of 94.17 for healthy eyes and 99.99 for red eyes.

TABLE. II. LABELLED OUTPUT OF HEALTHY EYES WITH ACCURACY

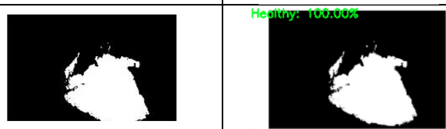
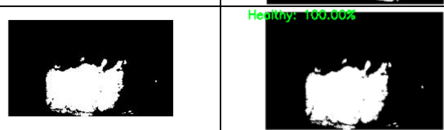
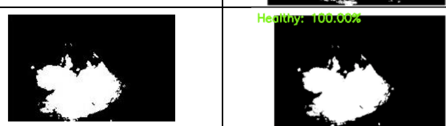
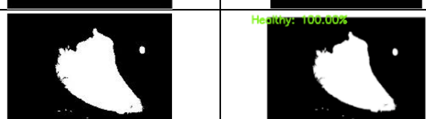
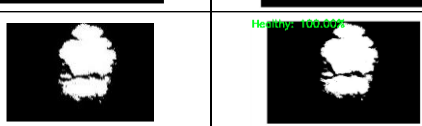
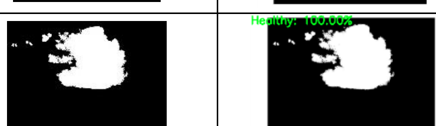
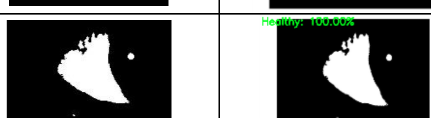
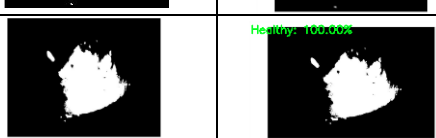
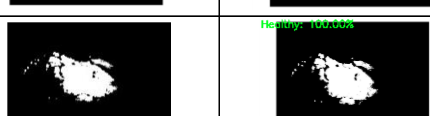
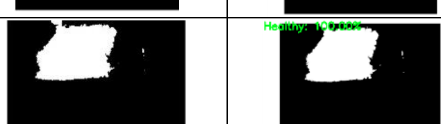
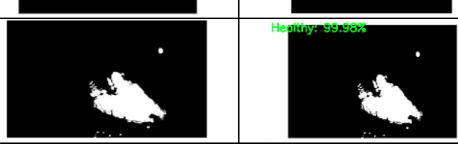
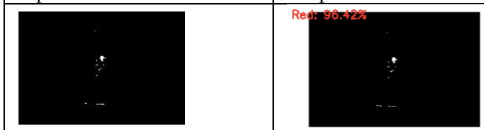
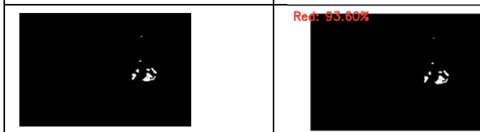
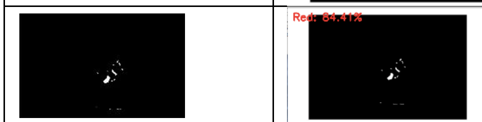
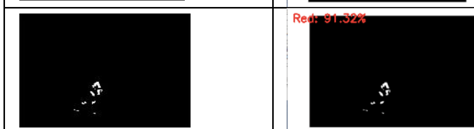
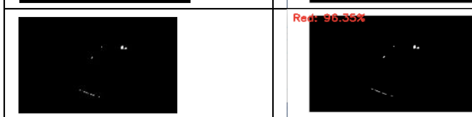
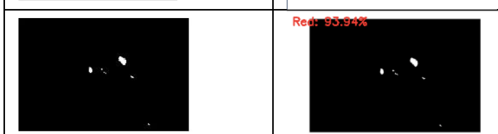
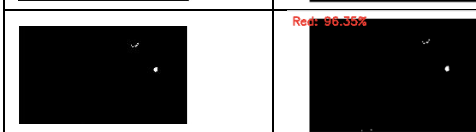
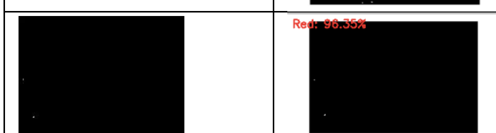
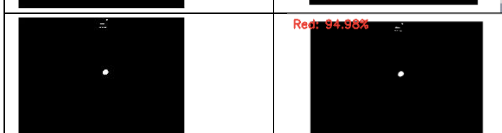
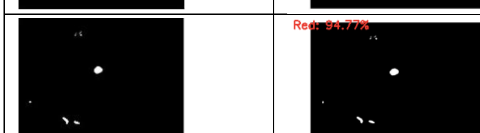
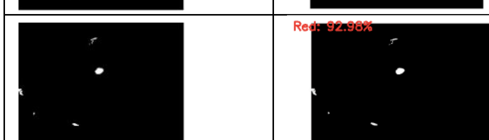
Input	Output	Accuracy
		100%
		100%
		100%
		100%
		100%
		100%
		100%
		100%
		100%
		100%
		100%
		100%
		100%
		99.98%

TABLE. III. LABELLED OUTPUT OF RED EYES WITH ACCURACY

Input	Output	Accuracy
		96.42%
		93.60%
		84.41%
		91.32%
		96.35%
		93.94%
		96.35%
		96.35%
		94.98%
		94.77%
		92.98%
		96.33%
		96.37%

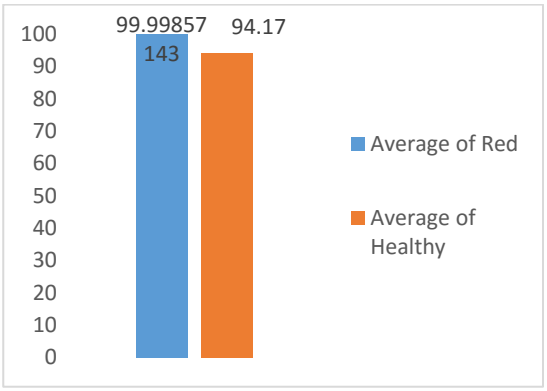


Fig. 3. Average Accuracy of Red and Healthy Eyes.

Fig. 4. Loss and Accuracy Plot of Red and Healthy Eyes w.r.t Epochs.

Graph in Fig. 4 shows the validation loss, training loss, validation accuracy and training accuracy of healthy as well as red eyes for 25 epochs, which clearly shows the efficiency of the proposed model.

VI. Conclusion

The main purpose of this study was to develop an effective and efficient CNN based classifier which could distinguish well between a healthy and red human eye in minimum time. The work was accomplished by using MATLAB for extraction of white portion from the eye and then feeding these images to the well-designed convolutional neural network. The CNN based model was coded in Keras, one of the efficient frameworks of Python. The results clearly indicate that our model is accurately classifying between the two types of images. This study will definitely cater to the need of rural India where the ratio of clinicians to the patients is very less. It also highlighted in this paper that neither the subjective method nor the objective method rules out the dependencies on the operators for evaluation and feature extraction. Therefore our proposed model minimizes this dependency by automatically extracting features and classifying the result in no time.

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Development and Evaluation of Massive Open Online Course (MOOC) as a Supplementary Learning Tool: An Initial Study

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***Abstract*—The popularity of Massive Open Online Courses (MOOCs) is prevalent among researchers and practitioners as a new paradigm of open education resource. Since the development of this technology may entail enormous investment, it is critical for institutions to clearly plan the process in designing, developing and evaluating MOOCs that fulfill the needs of target users while keeping the investment to a minimum. Evaluation plays a vital role in assuring that the developed product meets user's satisfaction. This study presents the process of developing a MOOC as a supplementary learning tool for students in a higher education and its usability evaluation which are rarely discussed in detail in prior literatures. Evaluation was done through a questionnaire and the items were adapted from Computer System Usability Questionnaire (CSUQ). The MOOC development process in this research which was based on the ADDIE (Analysis, Design, Development, Implementation and Evaluation) model and the MOOC usability evaluation results enrich existing literatures on MOOC. Overall, findings showed that users were satisfied with the developed MOOC with most of the items gained high mean score above 4.00. When respondents were asked to comment on the strength of the MOOC, the most prominent one turned out to be the MOOC's ability to make students' learning easier.**

***Keywords*—MOOC; development; usability evaluation**

I. Introduction

The evolution of Massive Open Online Courses (MOOCs) was first initiated in 2008 through a course of Connectivism and Connective Knowledge [1]. Since then, this technology has been adopted by numerous educational institutions through various MOOC platforms such as Coursera, Udacity, edX and many more. The advantage of MOOCs is not only as a modern form of online learning. They are also well known as an innovation in open distance education as a step forward in offering more learning opportunities and inspiring lifelong learning [2], [3]. This is possible due to the nature of MOOCs which allow free access and unlimited number of participants. As a result of the various benefits that this technology can bring forth, it is natural that MOOC has garnered immense interest worldwide.

However, despite the numerous benefits of MOOCs, the expensive and arduous production of this technology can be a concern and barrier to educational institutions [4]. Hence, it is imperative to have the design and the development process carefully planned to ensure that the developed MOOC involved minimum effort and investment while still satisfying the needs of the target user. User satisfaction can be evaluated to improve the quality of the MOOC. One of the key initiatives by the Malaysia government for higher education is to transform common undergraduate courses into MOOCs and to practice blended learning [5]. Therefore, educators who are not familiar with or have not used this technology yet can start an early practice by utilizing this technology as a supplementary learning tool for their students. This paper discusses the process deployed based on the ADDIE model in developing a MOOC and the usability evaluation among target users. The structure of this paper consists of a literature review, followed by methodology, results and discussion and lastly conclusion.

II. Literature Review

A. MOOC Development in Past Studies

The ADDIE model which refers to analysis, design, development, implementation and evaluation was generally employed by prior literatures when developing a MOOC. For example, Croxton and Chow [6] adapted the ADDIE model with systems thinking to develop a Web Design and Usability MOOC. During the analysis phase, target user was decided as the focus when designing the content. The design phase included setting objectives as well as strategies to achieve and to evaluate the objectives. After the content was developed, enhancement was identified and carried out during the implementation stage based on user feedback. Finally, the MOOC content was evaluated through formative and summative method. Rodriguez-Ch et al. [7] applied similar process based on the ADDIE model but with consideration of andragogical strategies to enhance interaction between elderly people and learning object. When designing the MOOC, storyboards were defined and the content was developed to include text, images, audios, interactions, animations, tests and quizzes. A study by Spyropoulou et al. [2] which also employed the ADDIE model for team-based development of MOOC assessed the content at every stage as well as at the end of all stages through interviews with the team members and surveys conducted with users.

There was also a previous research that constructed a MOOC life cycle which was similar with the ADDIE model. The life cycle comprised of exploration, planning,

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development, delivery and evaluation. Exploration level included identifying university's requirement as well as understanding target audience's needs and expectation through a pre-survey. Syllabus, goals and activities map were then outlined during the planning phase [8].

B. Successful MOOC Criteria

Among the criteria discussed by past studies for a successful MOOC are users must be engaged with the course and their intention and background need to be understood [9]. In addition, a MOOC needs to motivate users and encourage social networking, collaboration and peer supported learning among learners [10], [11]. A course outline with clearly defined objectives should also be provided including suitable content and assessment that satisfy learner's needs [12]. Furthermore, videos in MOOCs were stressed by prior literature to be in small chunks with less than 20 minutes of duration [11]. Past research also suggested for the materials in MOOCs to be downloadable [13].

C. Usability Evaluation

Usability was defined in ISO 9241-11 as the degree of efficiency, effectiveness and satisfaction of a product being used to attain specific goals [14]. It is essential for any product development to undergo usability assessment so that the product can be enhanced towards realizing consumer satisfaction [15]. The objectives of doing evaluation includes to detect the system's problems as well as to access the system's accessibility and users' experience of the interaction [15].

The Computer System Usability Questionnaire (CSUQ) by Lewis [16] has high reliability level and can been used by practitioners as standardized measurements of satisfaction [17]. The questionnaire comprises 19 items which were classified into four categories. The first category namely overall satisfaction covers all 19 items, system usefulness category measures 8 items, information quality with 7 items and interface quality with 3 items. System Usability Scale (SUS) developed by Brooke [18] is one of the commonly adopted usability evaluation questionnaires. It is a simple usability assessment questionnaire that consists of 10 items.

Based on the analysis done by prior research on standardized usability questionnaires, CSUQ had been used in systems of virtual learning, e-learning and student' information while SUS had been applied in assessing serious games and augmented reality software [17]. CSUQ was also stated as one of the universal questionnaires that cover the three usability criteria i.e. efficiency, effectiveness and satisfaction [17].

III. Methodology

This section is divided into two categories. The first part presents the development of MOOC while the second part discusses the instrument and the sample for data collection.

A. MOOC Development

The process used for developing MOOC in this study was as outlined in Fig. 1 which was adapted from Rodriguez-Ch et al. [7] based on the ADDIE model. There were some modifications done to suit the context of this research.

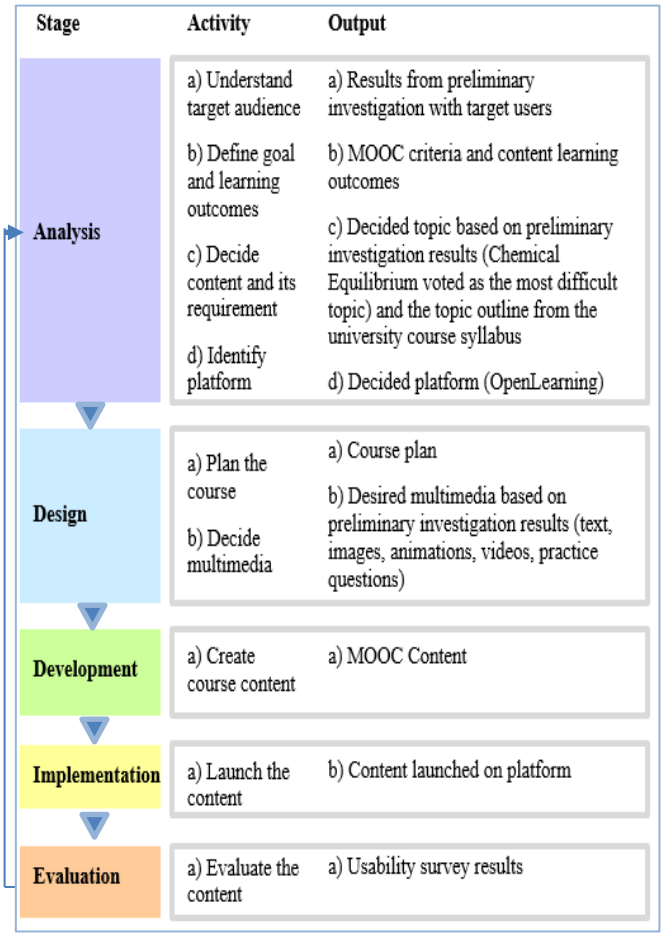

Fig. 1. MOOC Content Development Process.

1) Analysis: Since this research focused on developing and evaluating a MOOC as a supplementary learning tool for students in higher education, analysis was done to understand the needs of the target audience.

Firstly, the subject of the MOOC content was decided to be Chemistry as it was revealed to be one of the most challenging subject among 90 university students in a previous research [19]. Preliminary investigation was then conducted through an online survey among students who recently completed their Chemistry course in a higher institution in Malaysia. 73 students completed the survey and when asked to rank the difficulty of each topic, Chemical Equilibrium obtained the highest number of vote as the hardest topic. Therefore, the MOOC content to be developed was aimed to assist students in learning this topic in this university.

Since students also learned the topic through offline mode with their lecturer, the MOOC content served as a complementary learning tool. The goal of the developed MOOC was for learners to attain the learning outcomes listed in the Chemistry syllabus specified by the university which were in line with Bloom's Taxonomy. The developed MOOC content was decided to be launched at OpenLearning, the Malaysia's official MOOC platform [12].

2) Design: Once the content, goals and requirements had been determined during the analysis phase, a course plan was designed. According to the results of the preliminary studies, more that 50% of respondents chose graphic, online notes, animation, online quizzes and video lectures as the supplementary learning materials that they preferred to have. Taking this into account, the MOOC content which was divided into sections was designed to have these elements in each section. However, practice questions were opted instead of quizzes since the lecturer preferred quizzes to be conducted offline.

To inculcate collaboration and peer supported learning among users, a discussion forum need to be utilized. As recommended by M. E. Ismail [12], emphasis was put on the design of the content during this stage. Since a MOOC needs to be able to engage students, therefore, the videos have to be short, clear and interesting [21]. Attractive graphics and animation that were related to the content should also be incorporated as displayed in Fig. 2.

3) Development: The structured course plan was presented to the lecturer first before development ensued. As there were relevant video lectures found online, they were used and linked in the MOOC content to minimize production cost. Nonetheless, the videos were not made to be downloadable to respect copyright issue. The notes on the other hand were made available in text form on the platform as well as in downloadable pdf format. Notes and practice questions were designed and constructed together with the lecturer. All content was made sure that they aligned with students' Chemistry syllabus.

Peer collaboration and supported learning were encouraged through a few activities that allow users to ask questions and discuss problems with other participants as presented in Fig. 3. Reminders were included to notify students that their participation in discussions will carry marks.

4) Implementation: The content was uploaded on OpenLearning platform following the guidelines provided by the platform. The homepage of the content was as shown in Fig. 4. A user account was then created to test the content where amendment and improvement were made to eliminate any mistake and weaknesses.

5) Evaluation: Once the MOOC developer felt satisfied, the content was then evaluated among target users. Since the ADDIE model is an iterative process, the cycle started again with analysis phase where the findings obtained during evaluation were analyzed to improve the MOOC.

B. Research Instrument and Sample

The purpose of evaluating the MOOC content was to identify the content's flaws and users' satisfaction [20]. The evaluation was done through a survey and the questionnaire used had two sections with the first section focused on demographic information such as gender and user's MOOC experience. The second section on the other hand comprised close-ended and open-ended questions about the developed MOOC content.

The close-ended questions consisted of general questions about user opinion on the MOOC content as well as modified items of computer system usability questionnaire (CSUQ) developed by Lewis [16]. The open-ended questions were included to gain better insight of user's satisfaction towards the developed MOOC.

For the usability measurement, CSUQ was chosen since it has high level of reliability and it is suitable in the context of this research. The original items by Lewis [16] which had gone through reliability and validity process were modified to suit the context of this study. Additional items were also added to further understand user's impression, satisfaction and expectation of the MOOC content. Overall, 28 items were used for this research and they were classified into three categories namely MOOC usability, MOOC quality and MOOC interface. Each item was measured using a five-point Likert scale anchored on '1 = strongly disagree' and '5 = strongly agree'.

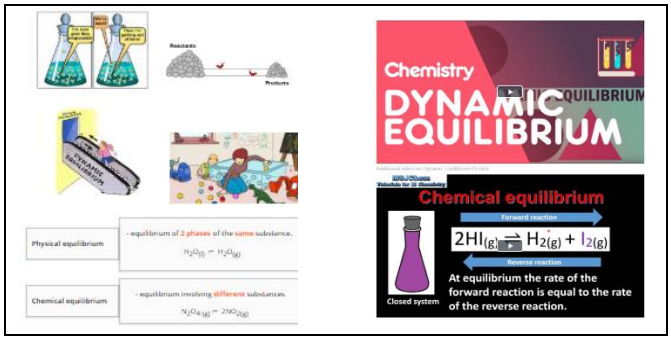

Fig. 2. Graphics, Animation and Videos used in the MOOC Content.

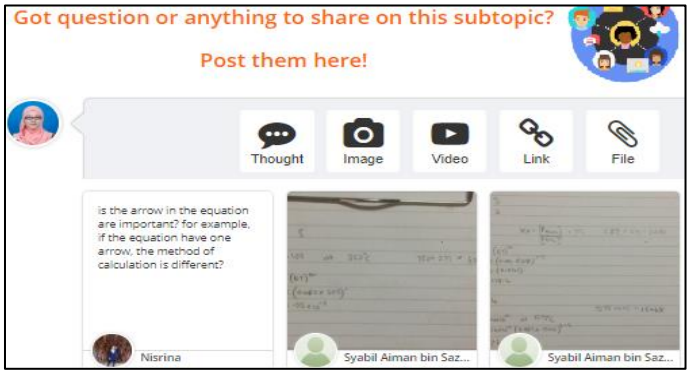

Fig. 3. Activities to Encourage Collaboration.

Fig. 4. MOOC Content Homepage.

The Cronbach's alpha for MOOC usability category was 0.876, for MOOC quality category was 0.855 and for MOOC interface category was 0.774. Since all the values exceeded 0.7, this indicated that the instrument used were reliable and the responses obtained had internal consistency with the respective items [22]. The quantitative finding obtained from the data collection was analyzed using descriptive analysis.

Since this is an initial study, purposive sampling method was done where all 21 students in one section were asked to use the MOOC content for 1 hour 30 minutes before they completed the questionnaire. They were first year Diploma in Mechanical Engineering students who currently undertook the Chemistry course in the university that the developed MOOC was targeted for. They had never heard of MOOC before the data collection so this was a new technology for them.

IV. Results and Discussion

This segment is organized into three sections. The first section presents and discusses MOOC usability evaluation results, the second section explores students' preference and opinion about the MOOC content and the third section explains research limitations.

A. MOOC Usability Evaluation Results

MOOC usability evaluation in this research had three categories i.e. MOOC usability, MOOC quality and MOOC interface. To interpret the quantitative data obtained from the questionnaire, the mean, mode and standard deviation of each item were studied using descriptive analysis. Mean score 1.00 to 2.33 was interpreted as low, 2.34 to 3.66 as medium and 3.67 to 5.00 as high [22]. On the other hand, mode represents the score with the highest frequency while standard deviation shows the dispersion of the data obtained.

1) MOOC Usability: MOOC usability items in the questionnaire measure the degree of effectiveness and satisfaction that students felt when using the MOOC Content. The results for MOOC usability in this research was as presented in Table I. Overall, all of the items obtained high level of mean above 3.67 except for two items i.e. U3 and U10.

The mode value for U3 which was 3 depicted that many respondents were not sure on whether the MOOC can make them learn the topic better or not. It was probably due to this being their first time in using MOOC and the time spent on the MOOC content might not be sufficient enough for them to be certain. Nonetheless, the number of students who agreed that they can learn the topic better when using the MOOC were more than those who disagree and neutral. In comparison with this item, user's perception that they can learn the topic faster when using the MOOC showed more positive result. This proved that MOOC can serve as a supplementary learning tool that can expedite students' learning and understanding process.

As for the item U10, despite the medium level of mean, the mode score was 4 and more than half of the respondents approved that they gained additional information from their friends through the MOOC. Based on the standard deviation values though, data for item U3, U4 and U10 were quite dispersed. Generally, the findings revealed that students were satisfied with the MOOC, with how easy it was to use the MOOC and to learn the topic through the MOOC.

2) MOOC Quality: MOOC quality in this study refers to the extent of user's perception that the MOOC has clearly defined objectives, suitable content and assessment. Table II summarizes the results for each item under MOOC quality category.

All of the items displayed high mean score except for moderate level of mean for Q12. Even so, the mode for Q12 was 4 and there was higher number of students who felt that the practice questions were sufficient than the total number of those who felt the opposite or was unsure. Regarding the practice questions and the hints provided being useful to them, strong approval was displayed based on the mean and the mode score. This finding demonstrated the importance of providing clues to assist students whenever they have difficulties in solving problems. The questions were also mostly approved for being clear and easy to understand.

Apart from that, majority of the users strongly agreed that the MOOC gave them messages to correct their mistake and let them recover quickly and easily. This is in line with the criteria of a good MOOC stated by prior studies in giving immediate feedback to users [10]. Furthermore, positive results were also achieved on students' satisfaction with the notes and the video lecture being useful to them, the organization of the content as well as the effectiveness of the MOOC in helping them learn the topic. Overall, it is noteworthy that the findings obtained showed that students were generally satisfied with the quality of the MOOC content even with minimum level of investment spent. On the flip side, the data for some of the items were pretty dispersed based on the standard deviation values.

TABLE I. MOOC Usability Results

No.	Items	Mean	Mode	SD
U1	Overall, I am satisfied with how easy it is to use this MOOC.	4.43	4	0.507
U2	It is simple to use this MOOC.	4.33	4	0.577
U3	I can learn the topic better when using this MOOC.	3.62	3	0.805
U4	I can learn the topic faster when using this MOOC.	3.86	4	0.964
U5	I feel comfortable using this MOOC.	4.14	4	0.573
U6	It was easy to learn to use this MOOC.	4.29	4	0.561
U7	I believe I am able to learn the topic productively when using this MOOC.	3.95	4	0.590
U8	I have fun learning the topic through this MOOC.	4.14	4	0.573
U9	I can share my knowledge with my friends through this MOOC.	3.95	4	0.669
U10	I gain additional information from my friends through this MOOC.	3.48	4	0.981
U11	Overall, I am satisfied with this MOOC.	4.29	4	0.561

3) MOOC Interface: Apart from the MOOC content quality, interface can also play a vital role in boosting students engagement and their learning process [23]. Hence, it is one of the aspect that MOOC developers need to be concerned with. There was only three items in MOOC interface category which were adapted from the original items of computer system usability questionnaire (CSUQ) [16]. The high level of mean score and the 4 mode score for all items as shown in Table III indicated that users liked the MOOC interface and agreed that the interface was pleasant and had all the functions and capabilities they expected it to have.

B. Students' Preference and Opinion about the MOOC

When students were asked about their preferred time of accessing the MOOC, the results shown in Fig. 5 were somewhat as expected as they would choose after school hours due to them being full time students. Regarding the type of device that they used to access the MOOC, more than half of them use both mobile phone and laptop.

Fig. 6 presents the percentage of students for their preference on whether they want the video lecture to be downloadable or not and whether they want the video lecture to be recorded by their lecturer. Not more than half of them actually need the video to be downloadable. It was probably because the MOOC content could be easily accessed at anytime and anywhere. In contrast, slightly more than half of the students wished the videos to be recorded by their lecturer. From one of the open-ended questions, when respondents were asked to share their opinion on how the MOOC content can be improved, Participant T said, "Video by lecturer also help student to understand". Since English is not the native language among students, another respondent expressed that understanding foreign English accent could be a problem at times. Hence, this is one of the aspects that can be considered for improving the MOOC content. Since the usability results were generally positive, it seems that this issue was not that critical and students still found the MOOC to be useful and effective for them.

Other suggestions for improvement shared by respondents include addition of interactive game, notes in .pdf format, more examples in notes, instruction on how to use MOOCs and making the MOOC compatible with all mobile phone types and iOS devices. Participant Z suggested a game format where users can win or lose points and finally gain something from the points they collected. This fun element can be one of the ways to enhance students' motivation and engagement.

Through other open-ended question, respondents were also requested to comment on the strength of the MOOC. Fig. 7 illustrated the frequency of some of the strength stated by students. Many of them conveyed that the MOOC makes it easier for them to learn the topic. One respondent shared that it was easy to just refer to one place to get all the information needed about the topic while Participant S added, "It feels like you have a pocket size notes even though it is a bit slow on the phone".

A few students also expressed that learning became easier as they could learn the topic anytime and anywhere. Similarly, Participant F said, "Easy to access, easy to learn and flexible in study time. Overall, comfortable study method." These responses were consistent with the well-recognized benefits of MOOCs mentioned in past studies.

C. Research Limitations

The results in this study are not meant for generalization due to limitation in sample size and sampling method. Survey respondents are also students who use the MOOC content to support their traditional learning. As MOOC users can also be someone who only learn through MOOC without face-to-face instruction, the results in this research cannot be generalized for MOOC in general. Since this is an initial study, follow-up research will be performed with a larger sample size.

TABLE II. MOOC QUALITY RESULTS

No.	Items	Mean	Mode	SD
Q1	The duration it took to complete this MOOC is just right.	4.00	4	0.548
Q2	The MOOC gives me messages for me to correct my mistake.	4.33	5	0.730
Q3	Whenever I make a mistake, I can recover easily and quickly.	4.24	5	1.091
Q4	The information provided in this MOOC is clear.	4.10	4	0.539
Q5	The information provided is easy to understand.	4.19	4	0.512
Q6	The content provided meet the requirement of the course syllabus.	4.29	4	0.644
Q7	The content is well-organized.	4.48	4	0.512
Q8	The video lecture provided is useful for me.	4.33	4	0.658
Q9	The notes provided are useful for me.	4.33	4	0.730
Q10	The practice questions are useful for me.	4.10	5	0.889
Q11	The practice questions are clear and easy to understand.	4.19	4	0.750
Q12	The number of practice questions are enough.	3.62	4	1.024
Q13	The hints given when I got incorrect answer are helpful.	4.29	5	0.784
Q14	This MOOC is effective in helping me learn the topic.	4.14	4	0.478

TABLE III. MOOC INTERFACE RESULTS

No	Items	Mean	Mode	SD
I1	The interface of this MOOC is pleasant.	4.00	4	0.548
I2	I like using the interface of this MOOC.	4.00	4	0.548
I3	This MOOC has all the functions and capabilities I expect it to have.	3.76	4	0.700

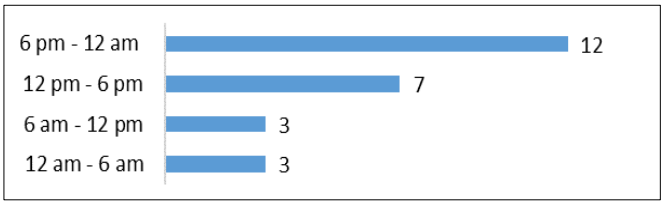

Fig. 5. The Number of Students who Chose the Preferred Time for Assessing MOOC.

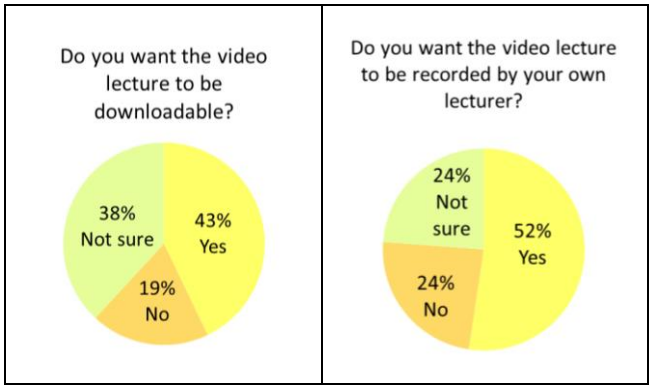

Fig. 6. The Percentage of Students for their Preference regarding the Video Lecture (n=21).

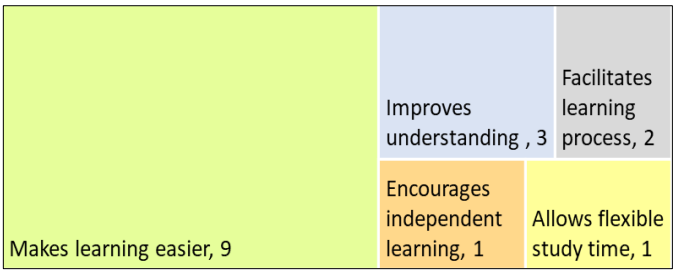

Fig. 7. The Frequency of the Strength of the MOOC Content Mentioned by Students.

V. Conclusion

The purpose of this research was to develop a MOOC and evaluate its usability among target users. From the findings, 25 usability items in this research displayed positive results with high level of mean, while three items gained moderate mean score. The three items measured students' perception on whether the MOOC enable them to learn the topic better, allow them to gain additional information from friends as well as provide enough practice questions. For future work, the results obtained from this research will be used to improve the MOOC content. Next, follow-up study will be done to evaluate the MOOC with larger sample size. Hopefully, the results presented in this study will enrich existing literatures on the usability of MOOC.

Acknowledgment

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Simultaneous Stream Transmission Methods for Free Viewpoint TV: A Comparative Study

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***Abstract*—Free Viewpoint TV is a system to view natural videos and allow users to control the viewpoint interactively. The main idea is that the users can switch between multiple video streams to find viewpoints of their own choice. The purpose of this research is to provide fast switching between video streams so that users experience less delay while viewpoint switching. In this paper, we discussed different stream switching methods in detail, including their transmission issues. In addition, we discussed various scenarios for fast stream switching in order to make services more interactive by minimizing delays. The quality of service is another factor which can be improved by assigning priorities to the packets. In addition, we discussed simultaneous stream transmission methods which are based on predictions and reduced quality streams for fast switching. Finally, we propose a prediction algorithm (Linear Regression) and system model for fast viewpoint switching and evaluate simultaneous stream transmission methods for free Viewpoint TV. The results indicate that the proposed system model improves the viewpoint switching and perform fast switching.**

***Keywords*—Free viewpoint TV; comparison of stream switching methods; video stream switching; fast switching; simultaneous transmissions; linear regression**

I. Introduction

Video streaming is getting popularity in communication and networks in this information age. It is used in many areas, e.g. live sports, education, entertainment (live/On-demand), etc. Voice over IP (VoIP) [1] has made major changes in telecommunications sectors by replacing circuit switching technology. The video streaming can be provided according to requirements and demands of applications by unicasting, multicasting, broadcasting or peer-to-peer. Different coding techniques are used for the transmission of multimedia streaming. People want fast switching between streams in living, on-demand, or Internet Protocol Television (IPTV) [31]. Free Viewpoint TV (FTV) is the latest technology which facilitates users to switch between multiple streams to find viewpoints of their own choice. This stream switching should be fast enough so that users should not be annoyed by delaying. This makes the technology more interactive, and users will really enjoy using this service. It is quite effective to use this technology in live sports events.

Users can watch any side view of the scene by switching between different viewpoints. Channel zapping time is the duration of time between channel change request by the user and the requested channel being available to the user. This zapping time should be short enough to provide fast channel change [33]. One way to provide fast channel change is to pre-join channels which are most likely to be selected next by the user [1]. Three-dimensional TV (3DTV) and FTV are critical applications of multi-view imaging. Both are based on rendering techniques, thus making the application much more interactive. 3DTV is also called stereo TV which generates 3-D depth impression of the scenes. FTV allows selection of a specific viewpoint of the scene in a particular direction, and that viewpoint is provided to the user [2]. Thus, to make applications more interactive to the users fast switching of viewpoint is necessary. This research describes different stream switching methods in detail along with transmission and switching issues related to those streams switching methods. The switching time varies from live to recorded events. The study shows that stream switching time more than 0.5 seconds is annoying to the users [3]. So, there should be fast switching between stream switching. Of course, the stream switching time varies from application to application. For example, if there is switching between some recorded scenes, then there will be fast switching, while in the case of live streaming, it will not be fast enough.

The main focus of this paper is to provide a deep knowledge of FTV based systems which are built on stream switching techniques in order to provide fast and interactive stream switching. The rest of paper is organized as follows. Section II provides related work which consists of transmission methods and video coding schemes. In Section III, stream switching methods are discussed and simultaneous stream transmission methods are described in Section IV. Section V presents the proposed system model and linear regression algorithm for simultaneous stream transmission. Finally, Section VI consists of conclusion and future work.

II. Related Work

This section describes related work which consists of transmission methods and video coding techniques for video streaming.

A. Transmission Methods

Transmission methods are categorized into four parts according to the application requirements and sender/ receiver relationship.

1) Unicasting: This transmission method is also called point to point method. The idea behind unicasting is to transfer data from one source to one receiver. This type of communication is very costly in terms of bandwidth consumption, as each host needs to connect server in order to receive the required data. Video on demand and communication over the phone are examples of unicasting in which each host is directly connected to the server for communication.

2) Multicasting: In this transmission method [4] information from the server can be sent to multiple hosts at the same time. This transmission method is used in streaming and in IPTV environment.

3) Broadcasting: In this transmission method information is sent to all hosts on the network. This transmission mode is quite useful when large numbers of hosts are connected to the server and information needs to be sent to all hosts. If some hosts on the network do not want information, then it will create extra load on the network and bandwidth consumption also increases which can lead to congestion problems.

4) Peer to Peer: In this transmission method end nodes are logically connected to each other; these end nodes are called peers. This method enables to share information between peers in a distributed manner. In earlier days peer to peer (P2P) networks were designed only for file sharing but now-a-day this method is getting much popularity in multimedia streaming. In P2P streaming architecture, a peer is involved with three roles, i.e. Source, Intermediate, and Destination. The source contains media content, and it shares with other peers. Intermediate peer receives media content and shares it with other Intermediate peers. Finally, destination peer receives intended content from one or multiple intermediate peers depending on network architecture [34]. Now we shortly describe two network architectures, multiple sources, and single source.

Multiple Sources P2P Network Architecture: In this network architecture, there exist more than one source peers for the requested stream. Each sender peer can send multimedia contents to one or several requested peers and each requested peer can receive contents from one or multiple sending peers.

Single Source P2P Network Architecture: In this network architecture [5], multimedia contents are stored in one source peer and can be transmitted to one or multiple requested peers. The intermediate node plays an important role by buffering contents and if any new peer requests then the intermediate node transmits to it.

B. Video Coding

In real time multimedia communications, bandwidth requirements are quite high. To handle this constraint, multimedia contents are first compressed and then sent over the network. Video coding [6] includes some data structures which are quite helpful during the encoding/decoding process. This data structure is shown in Fig. 1. A picture consists of several blocks. Each block has a size of 8 x 8 pixels. A group of blocks form a macroblock which is mostly used for motion estimation/compensation. A group of macroblocks form a slice which is used for resynchronization to the main data stream. This is done by inserting a unique bit sequence which is called the start code. Pictures can be encoded with the help of Intra-coded (I) and Inter-coded (P/B) pictures. In case of I pictures, it utilizes information of the same picture. However, in case of P/B pictures, it utilizes the information of previous or/and next pictures. These pictures are normally arranged into a group of pictures (GOP) where the 1st picture is I picture and the other are P/B pictures.

1) Intra coding: Intra-coded pictures are called I-frames in which encoding is performed by using the current frame and no reference to other frames is required. Outside of this current frame, no temporal processing is performed. Fig. 2 shows the process of encoding and decoding via intra coding. In the encoding process, image blocks are transformed via a Discrete Cosine Transform (DCT). Then DCT coefficients quantized, zigzag scanned (Q) and finally Variable Length enCoded (VLC). The decoding process is the reverse of the encoding process in which at first Variable Length Decoding (VLD) is performed then inverse Quantize function (IQ) and finally Inverse DCT (IDCT). This process is similar to JPEG compression [1].

2) Inter coding: Inter coding pictures are referred to as P-pictures. I- and P-pictures which act as a reference for other pictures are called reference pictures. The inter-coded pictures which take reference from previous and next pictures are called B-pictures. In video coding there exists a sequence of pictures which can be captured at a predetermined rate in which much information is static. This static information is called temporal redundancy which can be removed. The coding efficiency is much improved via redundancy minimization [7]. The basic idea behind inter-coding [6] is to find and recycle matching information from the reference pictures in decoding pictures. This idea is quite old, but it is still implemented in many video compression techniques.

3) Hybrid coding: Hybrid coding is a combination of both predictive and transforms coding techniques. Hybrid coding is more efficient and presently most coders are a variant of this technique. Fig. 3 represents the hybrid encoding containing ME, ME, PM, IT, etc.

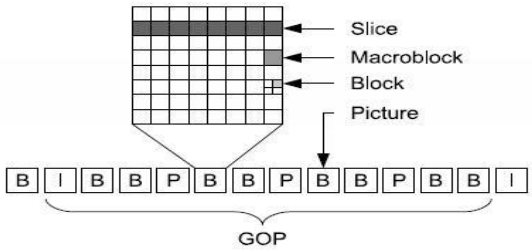

Fig. 1. Video Compression Data Structure (From [6] with Permission).

4) SP/SI frames: H.264 encoder [8, 9] has introduced two new frame types, SP- and SI-frames. These frame types can be used for the purpose of bitstream switching, error resilience and random access. Like I-frame, SI-frame utilizes spatial prediction and reconstructs picture which is identical to the SP-frame. In this case, SP-frame utilizes MC prediction.

5) H.264/AVC encoder: H.264/AVC is the latest video coding standard. The main idea behind the development of this standard was to improve the compression rate and rate-distortion efficiency [10]. It has introduced two new frame types (SP/SI-frames), which are explained in Section (II-B-4). There are many other new features introduced in H.264/AVC, like, Motion vectors over picture boundaries, redundant pictures, multiple reference picture motion compensation, etc. as shown in Fig. 4. In [11] all these features are explained.

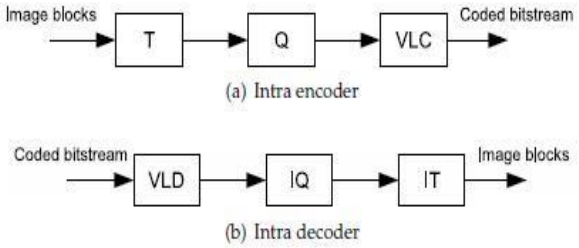

Fig. 2. Intra Encoding and Decoding (From [6] with Permission).

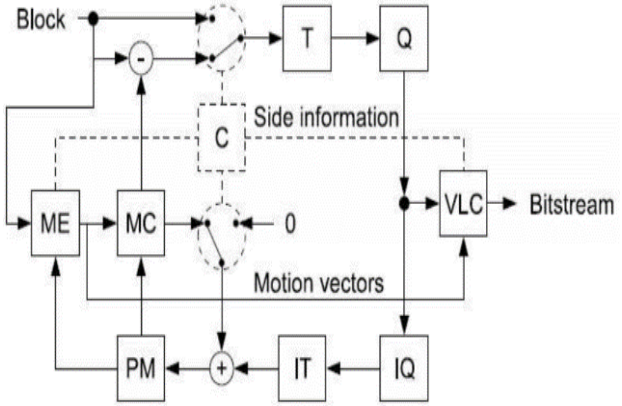

Fig. 3. Hybrid Encoding.

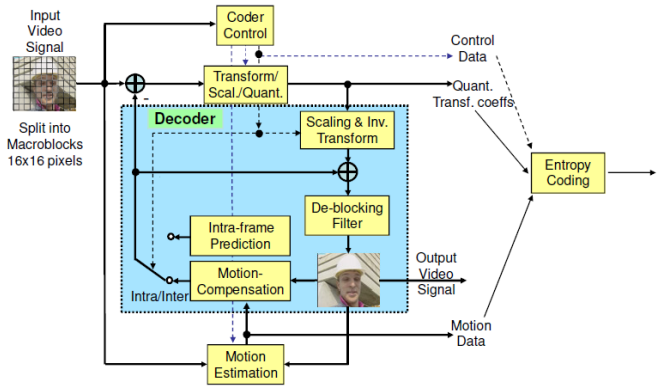

Fig. 4. H 264/AVC Encoder.

III. Stream Switching Methods

This section describes stream switching methods which are implemented in many applications. Live, on-demand, as well as recorded video contents, can be delivered to the receivers over the Internet by using multimedia streaming. Some methods which are used for video streaming are based on uncompressed video streaming, but most are based on compressed video streaming. The issue of compressed vs. non-compressed video depends on the application and environment. The idea behind non-compressed video stream switching is that it provides a very high-quality video which can be used for entertainment, live sports events, as well as education purposes. It requires high bandwidth. In compressed video streaming bandwidth requirements are not as high as for non-compressed video. Compressed streaming methods are most likely suitable for IPTV environment. In [32], analysis of IPTV evolution in Korea is presented in which key components of IPTV identified. The key findings of this study states that content plays an important role in the IPTV industry growth. It also highlights the understanding of the evolution for IPTV players and role of open innovation approaches in the development of the IPTV firm strategies.

A. Uncompressed Video Stream Switching

The method presents in [12,13] introduces a non-compressed 4k video transmission system. Uncompressed Super high-definition (SHD) images transmit and display 4096 x 2160 pixel resolution and 36-bit color with 24 or 30 frames per second, which is equal to 6.3 to 9.5 Gbps. The JPEG 2000 compressed SHD images range from 200-400 Mbps, which can be transmitted via common Gigabit IP network [14]. In [12] time code-based video switching, and stream crossfading are introduced for this purpose. Fig. 5 shows the network configuration of this system which consists of three video sources and one receiver via 10 Gbps network.

1) Time-code based video stream switching: In time code-based video stream switching, the time code is produced at each streaming server and transmitted with the stream via the same path to the receiver to calculate the difference in delay time. This delay is very significant to provide gapless video stream switching. The whole process is shown in Fig. 6. At the receiver end, timecode packets are received, and time codes of streams are observed, i.e., OT_A and OT_B. Control terminal calculates the difference between both observed codes for switching purposes, i.e., $DT_B = OT_B - OT_A$. The control terminal is responsible for sending ending and starting time to the streaming servers. These times are calculated via below equations.

$$ET_A=OT_{Areq}+MT \quad (1)$$

$$ST_B=ET_A+DT_B \quad (2)$$

Equation (1) shows the end time of stream A (ET_A) which is equal to the observed time of stream A when user requests for switching and MT is the margin time which is the time of arrival of ending packet to server A when the user requests. Equation (2) shows the starting time of stream B, which is based on the sum of ending time of stream A and the difference between observed codes.

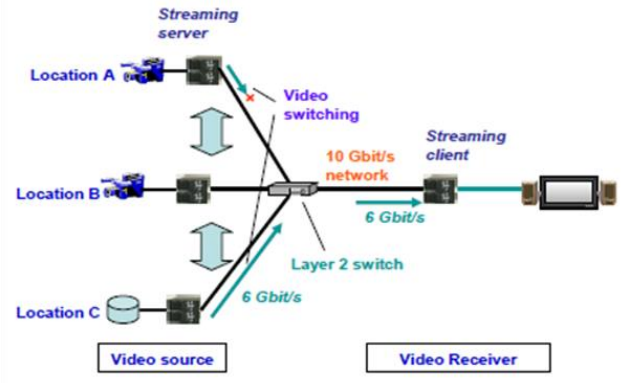

Fig. 5. Network Configuration [12].

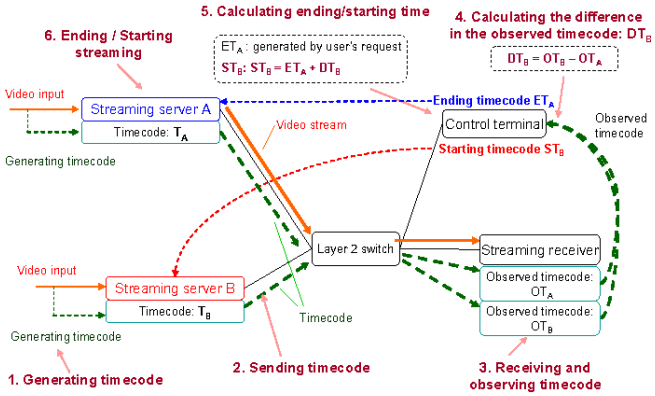

Fig. 6. Time Code-based Video Stream Switching Control [12].

The starting and ending of streams are based on the ET_A and ST_B. Server A stops streaming when it's timecode is equal to ET_A and server B starts when its timecode is equal to ST_B.

2) Prevention of bandwidth overflow with stream crossfading: The mechanism of video stream crossfading [13] prevents stream overlapping which leads towards bandwidth overflow problem during the stream switching process. When a receiver wants to switch from stream A to stream B, then server A decreases bit rate slowly and server B increases the bit rate slowly. For stream crossfading both sending and receiving servers require buffers. During stream switching from stream A to stream B at the transmitter end, server A (B) buffers the last (first) frame of stream A (B) and sends it throughout two frames. At the receiver end, last (first) frame of stream A (B) is received. When the last frame of stream A is received and played then switching is performed from A to B as a first full frame.

B. View Switchable Multi-View Video Transport

View switchable multi-view video transport [15,16] is a system which is based on IP multicasting and an example of 3D IPTV. It is suited for both videos on-demand as well as live multimedia applications. All the implementations of this technique are software based which enable to reduce hardware cost and ease of use for configuration and maintenance. Each acquisition server compresses each view individually for scalability purposes, which is transmitted over different multicast channels. The whole process is shown in Fig. 7.

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1) Issues with multi-view video transport: In real-time multi-view video transport based on 3D IPTV, two things are important which are, encoding efficiency and complexity. By decreasing the redundancy between multi-view videos, the size of multi-view videos can be reduced but this, in turn, made random access to multi-view video more difficult. In multi-view video transport, each view is encoded independently which is an attractive idea for real time environment, but it cannot exploit redundancy.

D. Video Streaming over Peer-To-Peer Networks

Nowadays sharing of multimedia contents between users is getting much popularity. Peer-to-Peer (P2P) [17] has made it pretty much easy and fast to share multimedia contents with each other. P2P networks consist of a large number of heterogeneous computers called peers. These peers act as client and/or server at the same time. These peers can directly communicate with each other and can share contents directly. P2P networks work in two modes, Open after downloading mode and Play while downloading mode. In the open after downloading mode, media contents are played after downloading all contents from a file or other peers. In Play, while downloading mode, contents are played while downloading is in progress. This mode is used in streaming and it takes lesser memory. Moreover, the client does not need to wait for the download to complete. Due to the dynamic nature of P2P networks, these are not reliable; any peer can enter or leave the network without prior notification.

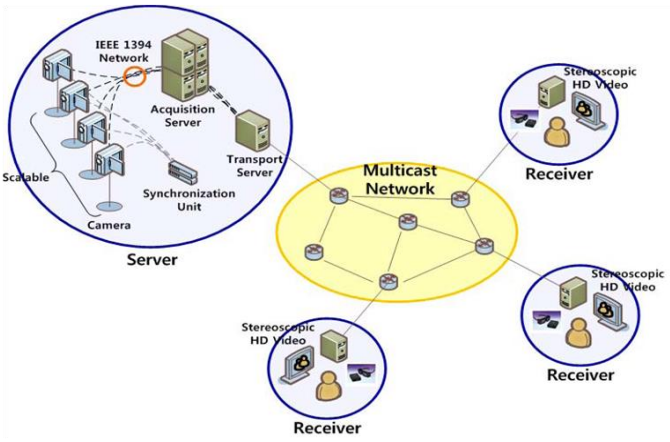

Fig. 7. Multi-View Video Transport [15].

1) Issues with P2P streaming: There is a problem in peer selection mechanism that if there are a large number of active peers sending the same video content then selection of a large number of peers for video transmission leads to extra overhead for establishing and monitoring those peers. Due to the dynamic nature of P2P, reliability is also another factor to consider.

E. Stream Switching based on GOP

The basic idea behind channel switching in Group of Picture (GOP) is synchronization points which are used for channel switching [18]. GOP is the organization of different frames in a specific order. It usually starts with a synchronization frame (I-frame) followed by P and B frames, which simplify the stream synchronization. Fig. 8 shows the process of channel switching by the GOP. It also shows the distance of I-frames as the quotient of the number of frames per second (fps) and the number of I-frames per second (RG). In today's IPTV systems, it is prevalent to use GOP to enable synchronization to the transmitted streams (channels). This technique is quite helpful and easy for stream switching and information loss recovery.

Let's consider a client is synchronized with channel A at the start. At the time "a" it requests for switching from channel A to B. The client then sends an IGMP to leave a message to stream A and then starts receiving stream B. The client waits for the I-frame to receive as it acts as a synchronization point for the client decoder. The frames received during this process will be discarded [19]. When the synchronization frame is received entirely and decoded, then the client is synchronized to the new stream (B).

1) GOP packet loss: I-frames solve information loss during transmission. Let's consider a client is receiving the channel A, and at time "c" it gets an erroneous frame, this means that now the reference to the previous frame is removed. Now the decoder will wait until an I-frame is received to decode the received frames. During this process, the frames are received, but the decoder did not decode. At the time "d" the client received and decoded the I-frame, and now the decoder is synchronized to the stream and frames will be decoded onwards [19]. This process is shown in Fig. 9.

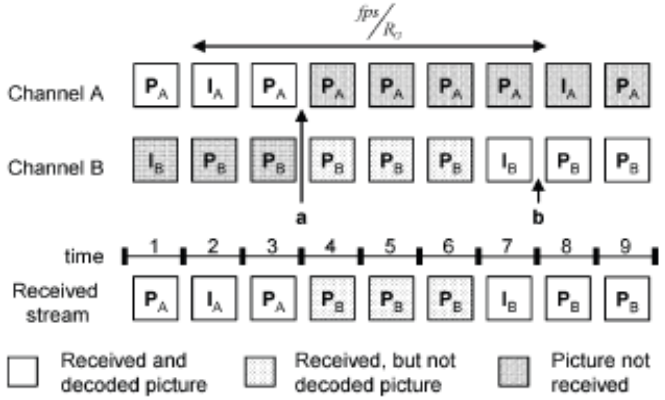

Fig. 8. GOP Channel Switching [19].

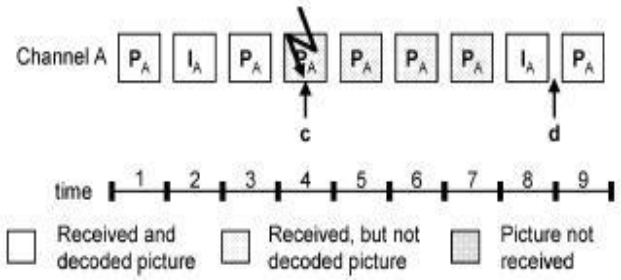

Fig. 9. GOP Packet Loss [19].

F. Synchronization Frames for Channel Switching

In this switching strategy [19], less channel switching and less of information are assumed, so it is redundant to send I-frames at a static rate. In SFCS synchronization, synchronization stream (I-frames) is separated from the main stream. In this technique, one channel is composed of two data streams. One stream consists of P-frames, which is the mainstream, and the other consists of I-frames, which is called the synchronization stream. Fig. 10 shows switching process from channel A to channel B. The client requests for switching from channel A to channel B at the time "a" and joins to the sync channel B. The client then waits for traffic to come and sends to the decoder. At time "b" client is synchronized to stream B. After that it leaves the sync channel and joins the main stream. In this switching strategy, unwanted traffic is prevented by late joining the mainstream. The main advantage compared to GOP is the bandwidth reduction for the specified channel because there is less number of synchronization frames.

1) SFCS information loss: The information loss recovery is pretty much the same as SFCS channel switching. If one or more data packets are corrupted, then synchronization to the stream is lost. This issue is resolved by resynchronization to the stream-like channel switching. As shown in Fig. 11, at time "c" the client receives information loss frame at channel A and then leaves the mainstream and joins sync stream of channel A. The client then waits for traffic on the sync channel and transfers to the decoder and finally synchronized to the mainstream at the time "d." The client leaves the sync channel and joins the main channel.

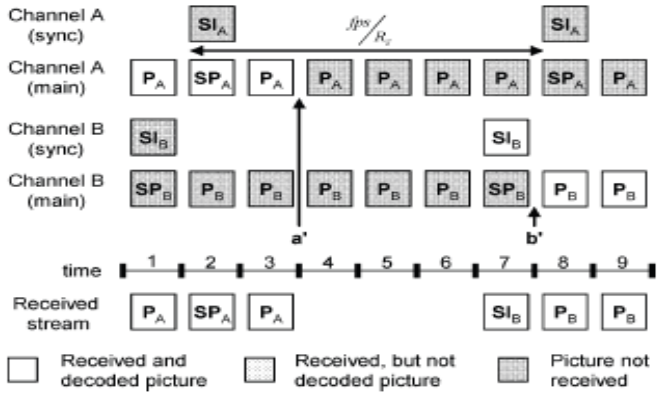

Fig. 10. SFCS Channel Switching [19].

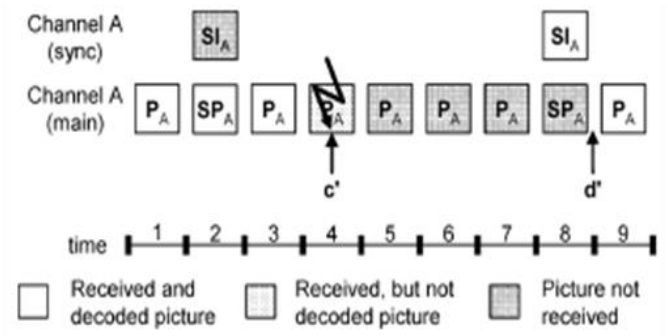

Fig. 11. SFCS Packet Loss [19].

2) Transmission issues and video quality: The factors which are mostly used to handle the transmission and quality of the video include priority encoding transmission, unequal packet loss protection, and priority dropping techniques. In wireless networks, mobile networks, and on the Internet, most packet losses are due to congestions, fading, and interference on the channel during communication [20]. As video contents are transmitting via multicasting, so those contents must be delivered to all recipients. Today many applications use protocols which use retransmission for missing contents in case of packet loss [21]. So, in the case of lossy networks implementing these types of protocols is difficult.

G. Fast Stream Switching

In IP networks, live streaming is mostly done through multicasting. In this scenario when any user wants to switch from one stream (channel) it simply issues channel switch command and switches from one channel to another. The time between leaving from one channel and join the other is called channel switch time [22]. This channel switching time is very important. The long channel switching time is pretty much annoying to users. The channel switching time less than 0.5 seconds is acceptable but more than that is annoying.

The channel switching time is varied in the case of recorded and live videos. Let's consider the case of channel switching in the IPTV environment. When a user wants to change the channel, it issues IGMP leave a message to the nearest router and after that by issuing IGMP join message, joins the new channel [6]. This joining of the new channel depends upon the availability of the stream. If the stream is already available, then the channel switch time will be less. Otherwise, it results in delay. In recorded videos switching, time is less as compared to live events. As after sending the join IGMP message, IP-STB at client side needs to wait until the packets arrive from the new stream. The identification of a new stream at the client side is based on I-frames, and after the identification, the decoding process starts. I-frames keep track of all the streams and have all the information about the streams. The distance between I-frames in the stream also depends upon the stream switching time and varies from zero to a reasonable amount of time.

There are many techniques used for fast channel switching. These techniques are implemented and are based on the requirements and network configurations. Boyce and Tourapis [23] proposed a new technique for fast channel switching in which low-quality stream is multiplexed with the normal stream. These multiplexed streams are transmitted and at the receiver end, de-multiplexing and decoding process is done. In this technique, the multiplexing equipment should be placed near the client, for example, DSLAM or advanced IP switching equipment. This technique works in a DSL environment and for video on demand (VoD). This idea somehow relates to the SFCS as discussed earlier but is not pretty much as in SFCS both sync and main streams are transmitted on different multicast addresses.

H. Ray-Space based FTV Systems

With time, the demand for the number of views is increasing as compared to the number of pixels. A ray is a virtual space which can be created by multi-view images. In [30,31] a ray based FTV system is presented in which capturing, encoding, decoding and view generation is discussed in detail. This system is based on realistic viewing and free navigation on 3D scenes. The trend is now shifting from wired to wireless transmission and from computers to mobile devices which have limited computation power, memory, battery, etc. An energy-aware adaptive free viewpoint video wireless transmission system [28] is aimed to deal with issues mentioned above by minimizing encoding rates and energy consumption. The experiments on the acquisition and processing of video for FTV [29] shows that such kind of simple and cost-effective systems are implementable very easily. With the rapid advancement in cellular technology, a system based on the broadcasting of FTV over long-term evolution networks [30] is proposed with some constraints of network and transmission issues.

IV. Simultaneous Stream Transmission Methods

This section presents simultaneous stream transmission methods. Stream transmission methods play an important role in any video streaming system. Many constraints in the system can be handled by appropriately using these methods. These constraints include bandwidth constraints, network congestion, etc. Moreover, these methods are quite helpful for fast viewpoint switching in FTV.

A. Simultaneous Transmission of Multiple Streams

The most popular way of simultaneous transmitting of multiple streams is multicasting. However, multiple streams can be transmitted via unicasting. The selection of these techniques depends upon the application environment as well as bandwidth constraints. In 3DTV and FTV, both these strategies can be implemented. We are going to talk more about the two flavors of multicasting. These are network layer multicast and application layer multicast. Among these two, application layer multicast is proposed in this simultaneous stream transmission method.

1) Network layer multicast: In network layer multicasting, the transmitter sends each packet only one time. At multicast enabled routers all these packets get together and are forwarded to other routers and hosts as needed. This strategy is most efficient, but it is not implemented broadly as it requires multicast-enabled routers. So, most network providers don't bother to replace existing equipment because it requires

much cost and may be some network downtime. Albeit, many new routers are multicast enabled but many network providers disable this functionality due to security reasons. So, this strategy is mostly not implemented widely.

2) Application layer multicast: In the application layer multicasting, the functionality of packet forwarding, duplication, and management is shifted to end hosts, and it is done through software application instead of hardware devices. This strategy is not as efficient as network layer multicast because some packets get duplicated and also may require more hops to reach the final destination. It is very easy to implement, and also it does not require much investment for buying hardware, so due to these factors, it is widely implemented in many network environments. In [24] application layer multicast is used for transmission of the selected number of multiple streams. These streams are quite helpful to render video from its current viewpoint.

3) NICE Protocol: NICE is an application layer protocol which is generally used for transmitting multi-view videos. In this type of protocol, all the members of the multicast group form small clusters which are based on geographical areas. The distance of geographical areas is calculated via ping RTT. These clusters further makeup lower layer 'L_0' in a hierarchical manner. The most central member in every cluster is designated as the leader and upheld to next higher layer 'L_1'. This process is repeated until we reach a point where leaders in cluster 'L_n' become a member of 'L_{n+1}' and a single member becomes the root of the hierarchy at higher layer 'L_{nmax}'. The hierarchy in the multicast groups describes data delivery paths implicitly. This, in turn, eliminates the packet delivery tree states and control meshes. In the hierarchical tree, each host maintains detailed information about their closest neighbors which is also a big advantage as compared to other multicast protocols.

In [24] 3D delivery system is proposed for multi-view video transmission. In this system, overlay distribution trees are built for every camera view and for every depth map stream. Every receiver finds out specific parts of image-based rendering (IBR) representation for the purpose of their current view rendering and subscription of corresponding distribution trees. By using Kalman filter future viewpoints can be predicted and necessary streams are fetched in advance which provides fast switching.

4) Multicasting framework: Multicasting framework consists of one or more multicasting streaming servers. Every streaming server contains streams which correspond to different views of multi-view video data. Moreover, there exist some professional peers who implement the NICE protocol. The receivers execute client software at their side to request streams from a multicast peer which is already known and forward that stream to rendering software for rendering the view. This rendering software is based on IBR technique. The rendering module does two very important tasks. It first renders the current view from streams and then instructs the multicast client to request relevant streams [24].

5) Image-based rendering techniques: Image-based rendering (IBR) techniques are an essential part of 3DTV and FTV. These techniques are used to render views based on several streams. These streams are predicted based on Kalman filter or other prediction methods. Moreover, in 3DTV and FTV head/eye tracking system is used to track viewpoints and streams are captured based on that technique. The rendered viewpoints are called virtual viewpoints. The area of viewpoint rendering has attracted a lot of research interest. The basic idea behind IBR techniques is seven-dimensional plenoptic function [25]. It illustrates all available optical information in a given region.

6) Network and transmission issues: There are almost always constraints regarding bandwidth in real time applications. In the case of simultaneous transmission of multiple streams bandwidth requirements almost doubles which create a lot of problems. The implementation of multicasting strategies improves efficiency by reducing duplicate packets at the server side in the network. These strategies also pretty much useful to reduce bandwidth requirements at both transmitter and receiver ends. Independent implementation of compression techniques on every stream at the server side also helps a lot to reduce bandwidth constraints.

B. Simultaneous Transmission of Reduced and High-Quality Streams

One way to transmit reduced and high-quality streams simultaneously are via Multi-view video delivery system. In this delivery system, only those streams are transmitted to the receivers which are necessary for rendering their viewpoint. In this method, lower bit rate versions of a set of adjacent streams are also transmitted with the actual stream. So, during switching if an unpredicted viewpoint change happens then a reduced quality version of the stream is already available which can be decodable till the arrival of the actual high-quality stream. This, in turn, provides much better results in the view switching process and provides a sort of guarantee for fast view switching by minimizing delays of requested streams and providing reduced quality streams.

1) Video delivery system: Fig. 12 shows the architecture of the video delivery system. In this system, the multi-view video is transmitted to clients via an IP-network. At the time, 't' the receiver viewpoint is sampled and at the time't+d' future viewpoint is predicted via kalman filter. Here' is the prediction distance which is calculated based on network and decoding delay. This distance is actually the sum of both delays. After this distance, the requested stream gets started playing. The network delay is a common issue for both unicast and multicast architectures. In the case of unicasting, the RTT delay of connection establishment between client and server is called 'network delay'. However, in the case of multicasting network delay is referred to as join latency to transmit multiple streams. The decoding delay depends upon the coding structure. Compression efficiency is much better in the case of longer GOP size but it results in longer decoding

delay. This longer decoding delay can be accommodated by increasing prediction distance and it is made sure that I-frame has been received as well as the stream is decodable before displaying to the users. Moreover, with longer delays, the prediction becomes less reliable which in turn results in prediction errors and it is possible that wrong streams are fetched from the server. So there must be a tradeoff between compression efficiency and decoding delay to avoid recurrent prediction errors [26].

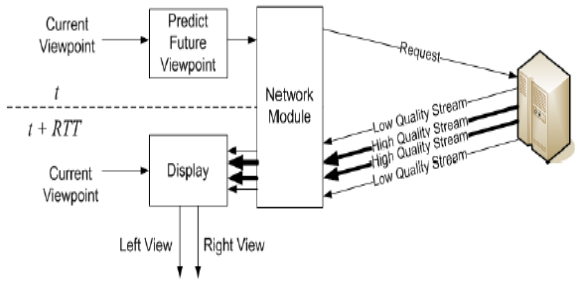

Fig. 12. Video Delivery System [26].

By using prediction on future viewpoint, streams are fetched from the server along with reduced quality neighboring streams. In the case of the free-viewpoint stereo system, the whole viewing space is divided into 'N-1' regions. Here N is the number of views in the multi-view sequence. In this system, the region 'Rn' is associated with 'V_n' and 'V_{n+1}' views. When the viewer moves from region 'R_n' to 'R_{n+1}' views 'V_{n+1}' and 'V_{n+2}' are displayed to the user. As future viewpoint is predicted, so by providing requested streams in advance, the delay of showing required stream is minimized which results in fast switching. In the case of prediction error, the reduced quality nearby streams are already available, which prevents the stoppage of stereo viewing and improves systems performance [26].

2) In a transmission system based on the simultaneous transmission of reduced and high-quality streams network and decoding, the delay is sort of problems for fast switching. These delays must be minimized to achieve fast switching. The requirement of bandwidth is also an issue to consider but it is not as much crucial as compared to the simultaneous transmission of multiple streams. As here we are going to transmit reduced quality stream with high-quality stream simultaneously. So, we can somehow sacrifice on this issue.

V. Proposed System Model

In FTV, the stream switching time is much reduced by transmitting the next probable requesting stream along with the actual stream. In this scenario, multiple calibrated cameras are mounted on the site (live sports event) and a unique scene is captured from all distributed cameras. Simultaneous transmission of multiple streams creates a lot of problems, e.g., service delay, bandwidth consumption, etc. So, there is a need to implement some strategy at server side to transmit that stream (probable stream) along with current stream which somehow helpful to minimize above mentioned issues and provide fast viewpoint switching. The transmission of the probable stream can be predicted by view prediction algorithm, namely, linear regression (LR).

Block diagram of the system model for simultaneous transmission of most probable next stream and the actual stream is shown in Fig. 13. This system model shows that there are four calibrated cameras distributed on the scene to cover the whole live sports event. There is implemented prediction technique namely 'linear regression' on the server to predict the client's desired view sequences and video-based rendering techniques to reconstruct views. We refer these reconstructed views as virtual views which are created when the client moves from one camera location to the other. Based on the prediction technique (LR algorithm) the client's viewpoint sequence is calculated and the regression line is marked. Based on the regression line, a new position of viewpoint is estimated.

A. Linear Regression Algorithm

Linear regression is a statistical method which is used to describe the relationship between two or more variables. These variables are called predictor and response variables. This method is suitable for a data model which is linear in model coefficients. This sort of linear regression is called least square fit. In real time applications like multimedia streaming, the implementation of such a linear model provides many benefits in terms of computational complexity and usability perspectives. Viewpoint prediction is achieved by using groupings of predictive data, received data and based on prior knowledge of working with the system. This method makes sure that output is linearly dependent on the input. This system model is described in equations (3) and (4) below.

$$\hat{Y} = \beta_0 + \beta_1 \times X \quad (3)$$

$$Y = \beta_0 + \beta_1 \times X + \varepsilon \quad (4)$$

Here '$\hat{Y}$' is the predicted output value and 'X' is the given input value which is the independent variable. '$\beta 0$' and '$\beta 1$' are parameters of the model. 'ε' corresponds to residual error from the regression line. These parameters are estimated from the training set which consists of n observations. These observations are structured as (X_1, Y_1), (X_2, Y_2), …, (X_n, Y_n).

$$\boldsymbol{\beta_1} = \frac{\sum_{i=1}^{n}(\mathbf{X_i}-\bar{X})\ \mathbf{x}\ (Y_i-\bar{Y})}{\sum_{i=1}^{n}(\mathbf{X_i}-\bar{X})^2} \quad (5)$$

$$\boldsymbol{\beta_0} = \bar{\boldsymbol{Y}} - \boldsymbol{b_1}\ \mathbf{x}\ \bar{\boldsymbol{X}} \quad (6)$$

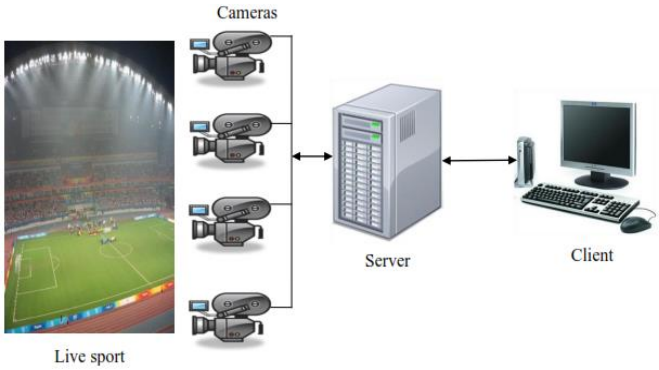

Fig. 13. Block Diagram of the Proposed System Model.

Here X and Y show the mean of all values for variables X and Y.

The calculations in equations (5) and (6) are carried out at the training level in order that the convergence of model functions is done. When these calculations are done and mentioned parameters are set up, the computation complexity at server side is much reduced and there are left only minor additions and multiplications which are performed by the LR algorithm [27], as in equation (3).

B. Regression Algorithm Explanation

This algorithm is implemented at the server side to predict the desired view sequences requested by the client. This algorithm makes it possible to predict the velocity of changing of viewpoints by the client and mark the regression line which shows the rate of change of the client's viewpoint. The algorithm's computational complexity is reduced to some extent due to the inherent nature of the system's working. Moreover, the accuracy of the regression line is also guaranteed.

In this system model, there are very fewer chances of errors during information acquisition because observations are done at the client side and the client enters the values. In this way, only two samples of training sets are generated which are used by the algorithm to provide robust regression line. As the user is changing the view by a certain velocity, so it's a free viewpoint operation. We propose that the predicted view is also transmitted simultaneously along with the actual stream. This provides fast view switching if the prediction is accurate. After this stage, it is checked at the client whether the viewpoint is accurate according to the client's request. If a viewpoint is accurate then it means that prediction is correct and viewpoint will be immediately provided to the client. In this case, fast switching of viewpoint will be guaranteed.

On the other hand, if the prediction is incorrect, i.e. viewpoint is not matching to the client's request then feedback is sent to the server which waits for the retransmission of 2nd data packet before algorithm's re-execution. When feedback is received at the server, the requested viewpoint is altered. This also makes sure that the request has been received and fulfilled. Finally, the regression line is computed, which shows a rate of change of viewpoint [28]. The previous delay is adjusted and the prediction process is resynchronized according to user's requirement. This process takes time, so the client will experience a delay while receiving a view of his own choice.

C. Viewpoint Prediction Calculation

The viewpoint prediction calculation is performed via the Linear Regression algorithm. In this algorithm prediction of viewpoint is calculated based on the previous history. The history contains user input data and observed values. In the following example, we have taken some data which contain both user input values and observed values. We calculate the parameters of the algorithm 'β0' and 'β1' from the data set. This parameter calculation is performed earlier and after that based on history, we apply the linear regression to get predicted values. These predicted values are actually our predicted view sequences. All these values are shown below in Table I.

TABLE. I. LINEAR REGRESSION DATA

Linear Regression		
Input Value (X)	Observed Value (Y)	Predicted Value (Ŷ)
1	1.00	1.45
2	2.50	1.825
3	1.50	2.2
4	3.75	2.575
5	2.25	2.95

β0 = 1.075, β1= 0.375

Based on predicted values, we draw the regression line, which is called the best-fitted line to all the observed values. This regression line is shown in Fig. 14. This line clearly shows the predicted value in a particular sequence and based on this sequence, the next probable viewpoint is estimated.

1) Network and transmission issues: There are also bandwidth constraints with this strategy. As we are transmitting multi-streams, so bandwidth requirements rise to double on the link. However, these constraints can be handled by applying compression techniques on the server side. The congestion on the bidirectional link between client and server is much reduced by applying the prediction strategy. As proposed prediction technique provides much better results [28, 29], so there are very fewer chances of errors. Thus, feedback communication between client and server is much reduced. This in turn also helps to minimize round trip delays.

D. Discussion

1) The proposed system model for FTV is shown in Fig. 13, which is based on client/server architecture. In this system model, we proposed that all the cameras are connected to the server, and the server is connected to the client via a bidirectional link. In linear regression algorithm is implemented at the server for most probable next view prediction. The author in [27] proposed that the requested viewpoint is transmitted to the client. We propose that the next predicted viewpoint is also transmitted along with the actual viewpoint. So, this will really help a lot towards fast switching. As this algorithm provides much prediction accuracy [27], so it results in fast view switching, and it is quite suitable for FTV.

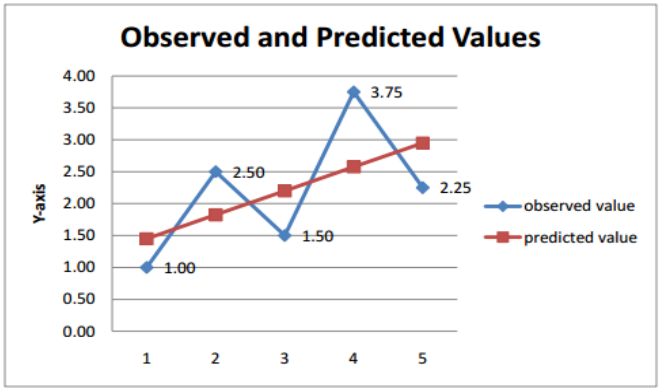

Fig. 14. Regression Line.

We have also calculated the regression line based on some data set. The regression line shows the sequence of viewpoints. As we can estimate the next probable viewpoint, so by transmitting that viewpoint along with actual viewpoint based on our proposed system model, fast viewpoint switching is guaranteed. Furthermore, our proposed system model provides a much better quality of service (QoS) in the sense that congestion on the network is much reduced by avoiding transmission of those streams which are not needed by the client at all.

2) System evaluation with respect to FTV includes quality of view rendering, bandwidth constraints, prediction accuracy, and fast switching. Based on simultaneous stream transmission methods as discussed earlier, we are now going to evaluate which one is best for FTV and why? In the case of simultaneous transmission of multiple streams, view rendering is performed at the client end, and multiple streams are transmitted from the server. The transfer of various streams has bandwidth constraints which may double or more bandwidth requirements, and it is a big problem in real time video streaming. It provides fast switching in the sense that if the user changes his viewpoint and the required streams for that viewpoint are already available then there will be fast switching.

In the case of simultaneous transmission of the reduced quality stream along with the actual high-quality stream, view rendering is still performed at client end, but bandwidth requirements reduced. As in this method, reduced quality streams are transmitting along with actual streams, so bandwidth requirements are somehow tolerated. Fast switching is also achieved in a better way as compared to the previous one in the sense that if the prediction for streams turns incorrect, then there are already available reduced quality streams which can be decoded. Thus, it avoids stoppage of stereo streaming and provides fast switching.

Lastly, simultaneous transmission of most probable next and actual stream provides much better results as compared to both previous methods. Bandwidth requirements are much reduced by transmitting predicted view along with real view via prediction technique, which provides many accurate results [28]. Since in this method there is no need to transmit streams at the client side so network bandwidth requirements also much reduced. So congestion on the network is also much reduced. As in this method, view rendering is performed at the server side, and the next probable view is transmitted along with the actual view, so, there will be much better results regarding fast switching.

VI. Conclusions and Future Directions

FTV is the latest technology which facilitates users to switch between multiple streams to watch viewpoint of their own choice. This stream switching should be fast enough so that users should not be annoyed by delaying of video stream switching. This makes the technology more interactive, and users will really enjoy using this service. It is quite effective to use this technology to live sports events. In this paper, we provide comprehensive knowledge about different components of FTV from several perspectives. We discussed different approaches according to categories like (1) Transmission methods and video coding (2) Stream switching methods, (3) Simultaneous Stream Transmission methods, etc. In addition, we propose a system model for FTV and calculate probable next viewpoint by using linear regression algorithm for fast viewpoint switching. The method of simultaneous stream transmission of actual and probable next stream is best from others.

We suggest implementing stream switching methods as well as simultaneous stream transmission methods based on predictions as future work. We think that the implementation of stream switching methods is quite interesting. Although, some stream switching methods have been implemented and tested already but it is still a quite emerging area. Simultaneous stream transmission methods based on FTV is quite an interesting area in multimedia streaming and a lot of research is in progress. Moreover, FTV with respect to 3DTV could also be an interesting future research work.

Conflicts of Interest: The authors declare no conflict of interest.

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Non-intrusive Driver Drowsiness Detection based on Face and Eye Tracking

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***Abstract*—The rate of annual road accidents attributed to drowsy driving are significantly high. Due to this, researchers have proposed several methods aimed at detecting drivers' drowsiness. These methods include subjective, physiological, behavioral, vehicle-based, and hybrid methods. However, recent reports on road safety are still indicating drowsy driving as a major cause of road accidents. This is plausible because the current driver drowsiness detection (DDD) solutions are either intrusive or expensive, thus hindering their ubiquitous nature. This research serves to bridge this gap by providing a test-bed for achieving a non-intrusive and low-cost DDD solution. A behavioral DDD solution is proposed based on tracking the face and eye state of the driver. The aim is to make this research an inception to DDD pervasiveness. To achieve this, National Tsing Hua University (NTHU) Computer Vision Lab's driver drowsiness detection video dataset was utilized. Several video and image processing operations were performed on the videos so as to detect the drivers' eye state. From the eye states, three important drowsiness features were extracted: percentage of eyelid closure (PERCLOS), blink frequency (BF), and Maximum Closure Duration (MCD) of the eyes. These features were then fed as inputs into several machine learning models for drowsiness classification. Models from the K-nearest Neighbors (KNN), Support Vector Machine (SVM), Logistic Regression, and Artificial Neural Networks (ANN) machine learning algorithms were experimented. These models were evaluated by calculating their accuracy, sensitivity, specificity, miss rate, and false alarm rate values. Although these five metrics were evaluated, the focus was more on getting optimal accuracies and miss rates. The result shows that the best models were a KNN model when k = 31 and an ANN model that used an Adadelta optimizer with 3 hidden layer network of 3, 27, and 9 neurons respective. The KNN model obtained an accuracy of 72.25% with a miss rate of 16.67%, while the ANN model obtained 71.61% and 14.44% accuracy and miss rate respectively.**

Keywords*—Driver Drowsiness Detection (DDD); face tracking; eye tracking; K-nearest Neighbors (KNN); Support Vector Machine (SVM); Logistic Regression; Artificial Neural Networks (ANN)

I. Introduction

Drowsy driving is considered one of the major contributors to road accidents all over the world. Every year, thousands of deaths or severe injuries are recorded due to drivers falling asleep while driving [1]. According to a report by the National Highway Traffic Safety Administration (NHTSA), driver drowsiness accounts for approximately 83,000 crashes, 37,000 injuries, and 900 deaths in the United States alone [2]. Another recent report by the World Health Organization (WHO) on road safety reveals that approximately 1.2 million road deaths occur annually from 2001 to 2013 [3]. Including the aforementioned, many other reports also identified road accidents as a rising cause of human deaths and a significant amount of these accidents were attributed to driver drowsiness.

Due to this severity, several types of research works have been conducted to prevent drivers from getting drowsy while driving. One of the solutions employed involved educating the drivers on the adversities of driving drowsy. This passive approach entails awareness of the effects of a distorted sleeping schedule, sleep deprivation, and the merits of getting a good night sleep [4]. Although these are requisites to completely eradicate drowsy driving [5], and could probably keep drivers alert at specific times, they are, however, not capable of determining whether a driver would remain alert in extreme situations like driving for a long period of time, not to mention, of proffering a solution if drowsiness occurs unexpectedly. Thus, an approach capable of measuring driver drowsiness in real-time is required. Moreover, there are drivers experiencing distorted sleep schedules due to the nature of their job, or with sleep disorders [6], who could still fall asleep even after adequate sleep.

However, as expected, numerous real-time approaches, providing on-board monitoring of drivers' drowsiness state have also been developed. This is, in fact, the focus of this problem domain. Techniques including physiological, behavioral, vehicle-based, and hybrid methods have been proposed and implemented. Among these techniques, physiological approaches are regarded as the most accurate driver drowsiness detection (DDD) method [7] with electroencephalogram (EEG) and electrocardiogram (ECG) being the most exploited approaches. EEG and ECG are used for tracking the driver's brain activity [8-10] and heart pulse rate [11-13] respectively. Although both approaches offer higher accuracy, they are actually not feasible in the real-world [14]. This is because they require electrodes being attached to the driver, which could cause discomfort as well as distractions [15, 16]. This would likely trace back to the initial problem they intended to prevent or solve.

Behavioral and vehicle-based methods, on the other hand, are non-intrusive. Even though they attain slightly lesser accuracy than their physiological counterparts, they have received significant interest from researchers. This is plausible

due to their portability into real-world scenarios. Moreover, according to [5], current researches on these two methods signify their accuracy is close to that of physiological methods. An example is the tracking of drivers' steering wheel movements (SWM) by [17], which obtained a reasonable accuracy. Authors in [15, 16] also used cameras and computer vision techniques to track drivers' facial and eye features as a means of detecting driver drowsiness.

This project, however, focuses on exploring DDD by tracking drivers' face and eye states. This approach was selected not only because it is one of the most promising techniques for accurately detecting driver drowsiness [15], but also because it is a potential solution for pragmatically achieving DDD ubiquity in the real world. The major hindrance of this approach, however, is its current high cost and quality of camera requirement. While SWM is a promising approach with low-cost application possibilities, SWM and other vehicle-based methods have potential for generating high false alarm rates [5], leading to more computational requirements.

This project aims to exploit face and eye tracking DDD approach as a test-bed for achieving a low-cost and non-intrusive DDD solution. To achieve this, a face and eye tracking model and several machine learning models were developed. The face and eye tracking model were used to detect if the driver's eyes are opened or closed. This tracking was done on a video dataset containing almost 2 hours of driver drowsiness states occurring during the day and night. The night data were very crucial in generalizing the accuracy of the machine learning models as drowsiness is predicted to occur mostly at night [18, 19]. Once the eye states were captured, they were passed to the machine learning models for classification.

Almost all DDD approaches use machine learning for classifying their drowsiness state. However, most of these approaches are usually limited to two or three models when evaluating their accuracy. With the driver's eye state data, over twenty models were developed employing K-Nearest Neighbors (KNN), Support Vectors Machine (SVM), Logistic Regression, and Artificial Neural Networks (ANN) classifiers for classifying the eye states into awake or drowsy. With this experiment, contribution of a face and eye state model was possible with a robust machine learning classification comparison for the face and eye tracking DDD domain.

So far, the paper vaguely touched on what Driver Drowsiness Detection is, while highlighting how the task at hand can be accomplished. But, in order to get to the crux of the problem, there is a need to understand the problem first, while focusing on the history and statistical study of the problem. This will potentially alleviate the concern caught on a developer's radar, to urge a solution at the earliest. The following section caters to these objectives coherently.

II. Problem Background

Road safety is a significant issue for many countries and many safety-related organizations. As population and urbanization grows, more vehicles and road users are expected on the highway networks. Thus, this leads to increased road management demand. The current upsurge in these factors (population and urbanization) has, however, stigmatized the current road management techniques. Recent reports are signaling the implications of poor or insufficient road management, yielding high occurrence of road accidents. As shown in Fig. 1 and 2, road accidents account for approximately 1.2 million deaths since the last decade [3]. These deaths were identified as the major causes of youth demise. Another report from Malaysia Institute of Road Safety Research (MIROS) indicates a total of 476,196 road crashes occurred in 2014 with 6,674 and 4,432 leading to deaths and serious injuries, respectively [20].

Different factors contribute to road accidents. However, the most prominent are those related to impairing the driver's response to road tasks. These factors, which include alcohol impairment, drugs usage, aging, distraction, and drowsiness, are responsible for 31% of fatal accidents in the US according to FARS [21]. Drowsy driving, as a result of these factors, has received significant attention as a major root cause of road crashes. According to the National Sleep Foundation (NSF), 37% of drivers in the US are guilty of drowsy driving and 23% have done it once in every month [22]. Another report by [23] revealed that 16.5% of lethal crashes and 12.5% of accidents, requiring admission of road users to hospitals, are as a result of drowsy driving.

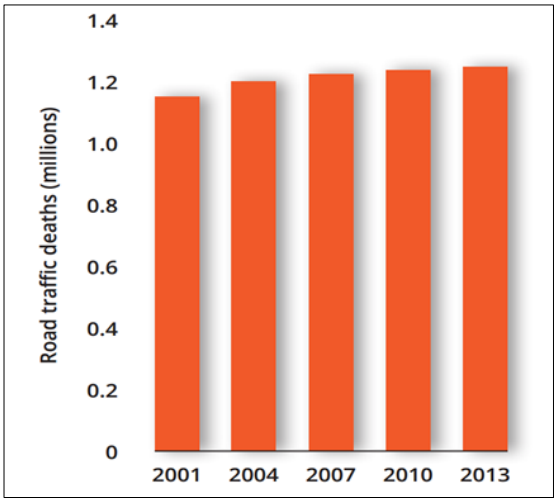

Fig. 1. Number of Road Deaths, Worldwide [3].

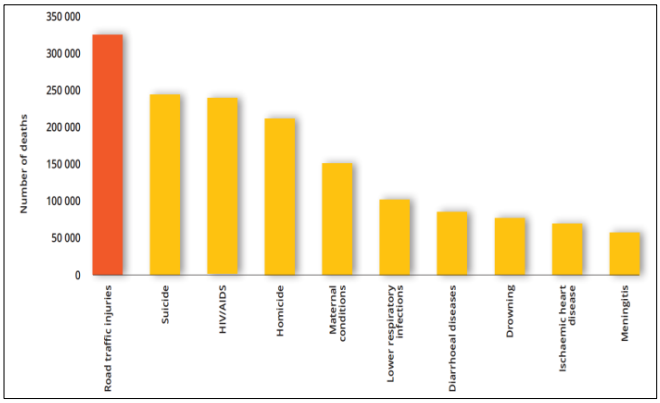

Fig. 2. Top Ten Causes of Death among People Aged 15-29 Years, 2012 [3].

Drowsy driving is considered a subset of impairment-related conditions that hinder the driver's response to required road tasks at the appropriate time. This state can arise either due to sleep disorders, sleep deprivation, or driving for a long period of time [6, 24]. When this occurs, the driver's driving performance, expertise, and decision making are adversely affected [16], thus leading to higher chances of accident occurrence. Although if the driver is not alone, he/she might be alerted by a passenger, however, this is not usually the case as most drowsiness-related crashes occur when the driver is alone [25].

Drowsy driving is a critical issue as its adversities do not only affect the driver but is also a threat to all other road users in the society. Several solutions, employing different approaches, to curb this problem have been developed and deployed. They include: subjective, physiological, behavioral, vehicle-based, and hybrid solutions [26-27]. Apart from subjective methods, which are questionnaire-based, and hybrid methods, which are just a combination of other methods, the other three methods are at the core of the DDD research domain.

Physiological methods, including EEG, ECG, and electrooculogram (EOG), are regarded as the most accurate DDD approaches [14-15,17,28-29]. A major contribution to their high accuracy is their capability of gaining direct access to drivers' inner body electrical signals, which can, however, be used for immediate detection of alertness changes [30]. Nevertheless, these methods are mostly restricted to lab environments [26].This is plausible because they are intrusive in nature, and can cause discomfort or distraction to the driver. Vehicle-based and behavioral methods, on the other hand, are non-intrusive [14]. Although their accuracy is slightly lesser than their physiological counterpart, a recent review by [5] indicates that their accuracy is catching up. The major issue with these methods, however, is the high cost of equipment required.

Within the DDD vehicle-based solutions ecosystem, Lane deviation [24,31] and SWM [17] approaches have received ample research significance, yielding adequate accuracies. Of these two approaches, SWM poses the utmost potential and has even been experimented on low-cost applications. However, most vehicle-based approaches are subjective to false alarms because they are constrained by vehicle type, driver's experience, road condition, etc. Author in [15] abates their accuracy because of the extra computation required.

Behavioral methods tend to bridge this gap (that is the excessive computation and intrusiveness) by offering competitive accuracy with tolerable computational expenses. Researchers targeting this method usually scope their driver behavioral definition to the drivers' facial features, since this is the most definitive physical part of the body that depicts a drowsiness state. As one of the most researched DDD method, several optimizations and comparisons have been made against its approaches. Percentage of eyelid closure (PERCLOS), a popular behavioral approach, is usually used as a benchmark against other DDD solutions' accuracy. Apart from PERCLOS, yawning detection and head pose tracking are also prominent approaches within this domain. However, there is still a need for a low-cost implementation of this approach. This is because previous works only employ expensive and high-quality cameras.

The current statistics, relating to road accidents in conjunction with those attributed to driver drowsiness, indicate there are still significant adversities on road highways. Although there is notably vast research on DDD, the impact of these researches in the real world appears to be dawdling. This is because only a few solutions are actually deployed into real-world scenarios. Presently, DDD solutions fall into one or more of these categories:

- Intrusive; thus, not feasible in the real-world.
- Very expensive; therefore, only available to minute fraction of road users.
- Affordable; but, lacking robustness.

A prospective method for mitigating the above mentioned is to perform DDD through the face and eye tracking. However, this method also has its own share of constraints, which are tied to the cost and quality of cameras required. Nevertheless, these constraints can be triumphed by channeling most of the required processes to the computational side of the system.

In order to achieve a solution balancing intrusiveness, affordability and accuracy, this project seeks to develop a face and eye tracking DDD model and evaluate it using vast classes of prominent machine learning classifiers. With this, their accuracies can be used for selecting the appropriate model for a device with constrained specifications. Thus, the aim is to find a solution to the problem of how driver drowsiness can be detected effectively by the means of a solution deployable in the real-world which balances affordability, intrusiveness, and accuracy.

III. Literature Review

Drowsiness refers to an awake state whereby there is an excessive urge or tendency to fall asleep. Whenever this occurs, the correspondent is usually afflicted by severe lethargy, and mental weakness, thus leading to depleted performance. Also, while it is common to find drowsiness being interchanged with fatigue in literature, both states are actually different concepts [32-33]. Fatigue, on the other hand, implies an extreme tiredness state which could be caused by several means including drowsiness or physical activities like exercises. Thus, drowsiness is a function of fatigue.

Drowsiness, also known as sleepiness, can emerge depending on several factors including being awake for a long period of time, sleep disorders, and sleep schedule distortion or medications [34]. Cases of sleep disorders include hypersomnia, sleep apnea syndrome, circadian rhythm sleep disorders, etc. [6] while sleep schedule distortion involves staying awake, or working for a long period of time, mostly due to working night shifts or driving through a long journey. Medications, on the other hand, involve using tranquilizers or sleeping pills [34].

The effect of drowsiness is significant in all domains. The cost of these effects, however, varies across each domain. Within the transportation domain, many reports have identified

drowsiness as a significant cause of road accidents leading to severe injuries and deaths [2-3]. A survey conducted by [6], seeking to correlate traffic accidents resulting from drowsy driving and the quantity of sleep the drivers had before the accident, revealed that 26.3% of accidents, in their sample, were caused by drivers that had less than 6 hours of sleep, the day before the accident. This implies that these drivers have higher chances of becoming drowsy while driving. Another finding by [35] led to a consensus that drivers who have slept for less than 2 hours within their past 24 hours are not competent to drive, and those who had slept for 3 to 5 hours have high chances of being impaired while driving.

All these issues concerning drowsiness have incited researchers to find a way for detecting and managing drowsiness. Managing drowsiness (not within the scope of this research) in and of itself is not an easy task [32], and so is its detection. Detecting drowsiness can be as simple as just looking at the correspondent's behavioral changes. However, this becomes a difficult task when the individual is alone [36]. Moreover, most of the drowsy driving crashes occur when the driver is alone [37]. Furthermore, DDD is known to be a challenging task because there's no standardized measure for detecting how drowsy the driver was or at a specific period of time [35,37]. Up till today, the current driver's drowsiness detection still suffers from either of varying drivers' characteristics, road environment or the vehicle type [14-15,38].

Although detecting drowsiness is not an easy task, several approaches have been devised to facilitate its detection. These approaches are usually categorized into either of the technological or non-technological [17], intrusive or non-intrusive [14,39], and objective or subjective approaches [40-41]. Within the driving context, these categories are mapped to five methods, which are subjective, physiological, behavioral, vehicle-based, and hybrid methods [42]. This mapping is shown in Table I.

A. Subjective Methods

Subjective methods involve assessing the drivers' current level of drowsiness by subjecting them to ratings in the form of questionnaires. These ratings are usually self-evaluated [40] or evaluated by experts watching the driver in action [15]. To detect the changes in a driver's drowsiness state, [14] conducted a pre-experimental, mid-experimental, and post-experimental Karolinska Sleepiness Scale (KSS) exercise. These ratings were the keys to define their drowsiness ground truth. [15], on the other hand, employed three experts to evaluate the drivers' state and a Johns Drowsiness Scale (JDS) was used. Other methods like the Stanford Sleepiness Scale (SSS), as shown in Table II, and Epworth Sleepiness Scale has also been applied by researchers.

As insinuated above, subjective methods are usually not used distinctively. They are used alongside other DDD methods to provide classification measures required for the detection process. This is mainly to enable accurate prediction of the driver's drowsiness state [17]. Furthermore, it is rare to find any DDD approach not utilizing at least one of these methods. However, they are highly vulnerable to deliberate false ratings or unintended bias [40].

TABLE. I. DDD APPROACHES AND DROWSINESS DETECTION CATEGORIES MATCHING

Categories / Methods	Subjective	Physiological	Behavioral	Vehicle-based
Technological	-	x	x	x
Non-technological	x	-	-	-
Intrusive	-	x	x	-
Non-intrusive		-	x	x
Objective	-	x	x	x
Subjective	x	-	-	-

TABLE. II. STANFORD SLEEPINESS SCALE (SSS) [43]

Value	Description
1	Feeling active, vital, alert, or wide awake
2	Functioning at high levels, but not at peak; able to concentrate
3	Awake, but relaxed; responsive but not fully alert
4	Little foggy; not at peak
5	Foggy; losing interest in remaining awake; slowed down
6	Sleepy; woozy; fighting sleep; prefer to lie down
7	No longer fighting sleep; sleep onset soon; cannot stay awake

Stanford Sleepiness Scale [43] and Karolinska Sleepiness Scale [44] are the two most widely utilized subjective measures within the DDD domain. SSS is a 7-point measurement scale (Table II) describing the current state of drowsiness of an individual. This method as employed by [45] is most likely be used to categorize driver drowsiness into only two states. This is because of the close relation of each scale. KSS, on the other hand, is a 9-point scale (Table III). A contrast to SSS, this scale is considered a robust scale capable of categorizing driver's drowsiness into different levels [46]. Authors in [14] and [18] used KSS to define five, and three drowsiness states of their systems respectively. Also, a review of literature relating to DDD by [5] indicates KSS is the most preferred scale of these two scales.

TABLE. III. KAROLINSKA SLEEPINESS SCALE (KSS) [44]

Value	Sleepiness Level
1	Extremely alert
2	Very alert
3	Alert
4	Rather alert
5	Neither alert nor sleepy
6	Some signs of sleepiness
7	Sleepy but no difficulty staying awake
8	Sleepy with some effort to keep alert
9	Extremely sleepy, fighting sleep

B. Physiological Methods

Physiological methods are regarded as the most accurate DDD methods [9,47]. These methods provide access to the inner body state of the correspondent. With this capability, they can detect drowsiness at a very early stage [47]. Several sensors have been developed to track the electrical activities of different parts of the body. However, the currently employed (and most important) sensors for DDD are those involving heart activity, brain activity, and eyes activity [33]. The processes of capturing these body signals are termed electrocardiogram (ECG), electroencephalogram (EEG), and electrooculogram (EOG), respectively.

Physiological methods are conventionally intrusive [14,39]. The sensors used for capturing the required data are specific electrodes placed relative to the external part of the body they are tracking. For EEG, the electrodes are placed on the head [8]. The electrode is placed on the chest for ECG [27], and close to the eyes for EOG [1]. The intrusiveness of such methods has impeded their prospect of being the top DDD approach. Because of this, researchers are extensively exploiting new approaches, such as steering wheel movements (SWM) [17] and face tracking [16]. These approaches are quickly becoming the domain's point of interest.

Nevertheless, research advancements still continue within the physiological scope. These involve increasing the accuracy threshold [48], reducing the intrusiveness [8], reducing equipment's cost, and developing mobile solutions [49]. Author in [49] tried to balance intrusiveness, cost, and mobility by developing a low-cost EEG system using a wireless EEG headband and a smart watch, which still managed to get a reasonable accuracy. Below is a review of the three most prominent physiological methods:

- Electroencephalogram (EEG)

This method involves the tracking of electrical activities in the brain [30]. Of all physiological approaches, the EEG is the most widely used and most accurate [9,49]. Fig. 3 illustrates the flow diagram of such a system and its specifications [49]. [8] developed a wireless based brain-computer interface for detecting the driver's drowsiness. This system collects the driver's EEG signal at a sample rate of 256 Hz by installing the electrodes and a wireless transmitter (Bluetooth) on a brain cap to be worn by the driver.

- Electrocardiogram (ECG)

This method involves tracking the heart pulse rate [50]. Several types of researches have been carried out to facilitate this [12-13], and lots of comparisons have been done in order to prove its competence with other popular methods. Author in [13] examined the heart rate variability (HRV) and compared it with popular EEG and behavioral percentage of eyelid closure (PERCLOS) methods. Their results show that ECG predictions match the two approaches. Furthermore, with an aim to mitigate intrusiveness, [50] uses electrodes placed on the steering wheel and a wireless ECG sensor node to capture the driver's ECG signals through the palm. This setup is shown in Fig. 4. These methods, however, proved ECG to be a significant contender in the DDD space.

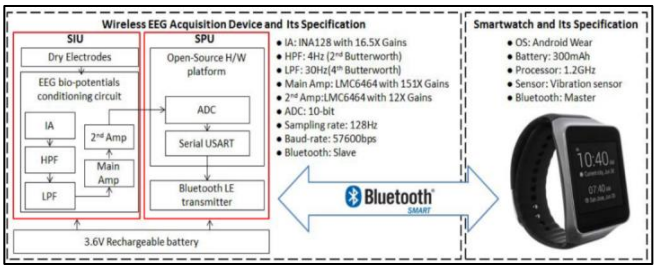

Fig. 3. Low-Cost and Mobile EEG System Diagram by [49].

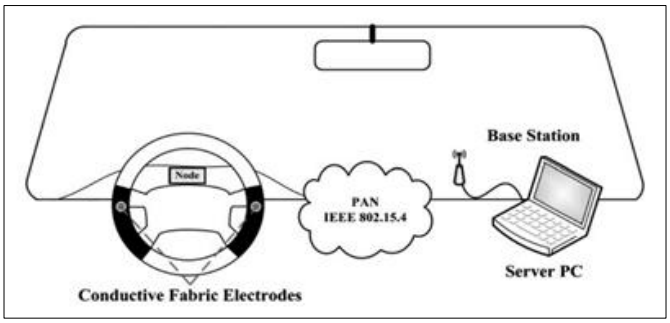

Fig. 4. ECG system architecture [50].

- Electrooculogram (EOG)

Like other physiological methods, EOG requires electrodes for data capturing. These electrodes, however, are used for tracking the electrical signals depicting the eyes' retina movements. Author in [1] conducted an EOG experiment with a sampling frequency of 512 Hz on 37 sleep-deprived subjects in a simulator. Although EOG signals are weaker than EEG signals, [47] proposed a system that was able to reach 80.74% accuracy.

C. Behavioral Methods

Unlike physiological methods, behavioral methods are non-intrusive [14]. They are capable of capturing the driver's drowsiness state without having any physical contact with the driver. These methods are the most explored DDD methods [27]. Percentage of eyelid closure (PERCLOS), a behavioral method, was one of the first and most commonly used DDD approach [5]. Rarely is there any DDD approach that does not consider PERCLOS. Other methods frequently use it as a threshold to validate their model [5,51].

As drivers begin to experience drowsiness, there are some physical changes that occur around their body- most, especially, around the head area [27]. These are the changes behavioral methods seek to track. Currently, the recognized changes within DDD scope are head nodding, yawning, and some varying eyelid states [27]. In order to detect these changes, behavioral methods usually go through a combination of video acquisition of the driver state and some computer vision techniques processes, [52-53] where computer vision encompasses both image processing and machine learning.

As stated above, the three main features targeted in behavioral methods are the head poses, yawning, and eye states. Several methods have been developed to determine either or a combination of these features. Author in [16] worked on a system tracking the eye state and head pose of the driver. Their

model defined three measures: head poses, eye index, and pupil activity. However, two of these measures are just part of the aforementioned eye state measure. Author in [15] also worked on eye states, and like [16], this measure was subdivided (into six separate measures). Other applications for yawning are also available and will be reviewed shortly.

While behavioral methods are currently popular, used in extensive research, these methods are usually impaired by individual specifics [14]. Many literature works realized this and mostly suggested that it tends to be too advanced for the time [15]. Author in [38] in an attempt to mitigate this issue included several drivers- specific thresholds like different eye shape, texture, and blinking patterns in their model. In [14], the author achieved theirs by incorporating several methods together. Other issues relating to behavioral methods include environment illumination, head rotation, and the cost and quality of the cameras used for video acquisition [26]. Below is a review of the three most prominent behavioral methods.

- Eye State Tracking

These methods involve making DDD decisions by extracting meaningful features from the driver's eye [54]. Features extracted are accumulated over a stipulated period of time so as to generate measurable variables for the actual drowsiness detection. Several measures have been defined and standardized within this context. These measures include PERCLOS, blink frequency, and velocity of eyelid opening and closing [5,27]. The blink frequency represents the number of times the eyelids close and open over a specific period of time. Fig. 5 represents a specific eye state interval for various eye state measures as part of a research in [15].

Lots of researches have been done with respect to the driver's eye state, thus it is regarded as one of the first and most accurate DDD approach [27]. Due to this, many comparisons are done against it. A comparative analysis done by [55], between eye closure and ECG (heartbeat signal), revealed that eye closure was more effective in detecting driver drowsiness than ECG. However, it is important to note that tracking the accuracy of eye states degrades, either when the driver is wearing glasses, in the presence of illumination or head position changes [27].

- Head Pose Estimation

This is a behavioral approach based on detecting whether the driver's head is nodding in a way similar to that of a drowsy person [17]. This process usually requires a 3D camera or a stereoscopic visioning. In the absence of a 3D camera, [16] used a 3D software (Blender) to create a 3D head model and continuously matched this with their 2D face sequence. Although it is highly probable for nodding to follow drowsiness, this is usually not the case as there are situations where drowsiness occurs without nodding, or probably, nodding occurs only when the drowsiness has been deeply infused [33]. In either of the two cases, it is evident that the accuracy and response time of the method would be degraded. However, this is recognized by researchers and this method is usually not used alone [16,56].

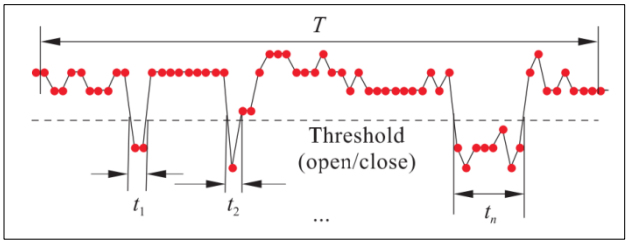

Fig. 5. Eye State Intervals for Measuring PERCLOS, and other Eye State Measures [15].

- Yawning Detection

This method involves tracking the driver's mouth [38]. However, like the head poses approach, this method does not always depict drowsiness [33]. Although this method is not usually used in isolation, [28,57] worked on systems solely for tracking the mouth and detecting driver's yawning.

- Vehicular Based Methods

These methods attempt to detect drivers' drowsiness by tracking changes in the behavior of the vehicles [5,27]. Several approaches have been developed to facilitate this, which includes steering wheel movements (SWM) [28,56], the standard deviation of lane position (SDLP) [59-60], and acceleration and deceleration fluctuations [27]. Of these three approaches, SWM and SDLP are the most popular [51,61]. Author in [17] worked on a low-cost SWM approach using a low-cost accelerometer and compared their results with other popular DDD approaches. Another implementation by [19] tracks the driver's lane deviation and then provides a warning to the driver to take action. However, if the driver does not respond to the warning, the system takes control and makes the correction itself.

Although vehicle-based methods have also recorded high accuracy rates, they are usually trailed by their high potential of false positive alarms. These have lead researchers to subject their systems to robust computations before reaching a reasonable accuracy. In order to reach the desired accuracy, [17] had to use several techniques and also compare their result with other methods. Many researchers, however, view this as a minor issue due to the computational power available today.

Conversely, SWM has been currently receiving much interest from researchers [5]. This is because of the possibilities of DDD based on the number of steering wheel corrections compared to normal driving conditions [27]. According to [5], many DDD solutions are currently targeting the development of low-cost SWM or the facial tracking approach. For SWM, [17] proposed a low-cost approach capable of obtaining a reasonable accuracy.

- Hybrid Methods

These methods involve the combination of any of the above DDD methods as a means for mitigating the weakness of each method when used individually [27]. These kinds of implementations are still at their infancy; however, the current implementations are indicating better results than other

methods used discretely [17]. In [14], the author developed a system using 23 measures including PERCLOS, SDLP and SWM which were captured through a driving simulator. Although their result did not attain the expected accuracy, their aim to consider individual specifics by correlating various approaches questions the results of current methods. Another implementation by [62], that combined vehicle-based and behavioral approaches, were able to deduce that combination of more than one method yields higher accuracy.

Table IV summarizes and compares all current DDD methods available. It clearly states the techniques, accuracy and tools used in each of the methods.

TABLE. IV. COMPARATIVE ANALYSIS OF CURRENT DDD METHOD

Author(s)	Objective(s)	Techniques	Accuracy	Tools
[15]	- Address illumination and head posture changes issues with DDD based on facial features	- AdaBoost - ATM - ASM - JDS	- 86% overall accuracy	- Driver simulation setup - 8 bits RGB camera
[16]	- Drowsiness detection by analyzing driver's eye state and head pose	- SVM - Viola-Jones Algorithm - ATM - POSIT algorithm	- 97.2% on pupil detection - 87.27% overall accuracy	- BioID and Boston University database - Camera - Blender 3D software
[14]	- DDD model that considers drivers specifics - Validate MOL model by comparing with OL and ANN model	- MOL, OL, and ANN - KSS	- 3 DL: MOL has 64.15%, OL has 52.7%, ANN has 56.04% - 2 DL: MOL has 88.6%, ANN has 83.3%	- Simulator setup - SCANeR studio software - Smarteye eye tracker and Pro software
[49]	- Develop a non-discrete DDD classification model	- EEG - SVM based Posterior Probabilistic Model (SVMPPM)	- 91.25% for alert - 83.78% for early-warning - 91.92% for full-warning	- Bluetooth Low-Energy - EEG headband with dry electrodes - Smartwatch - Matlab
[50]	- Measure driver fatigue and health condition - Provide a non-intrusive physiological means of DDD	- ECG - 100MHz sampling rate - HRV analysis	- not provided	- TinyOS - Zigbee - fabric electrodes - MCU TI MSP430
[13]	- Provide an HRV based system for detecting driver's fatigue early	- ECG, HRV - ANN - FFT	- 90% overall accuracy	- Matlab -
[8]	- Develop a wireless based brain-computer interface	- EEG - Clustering algorithm - 256Hz sampling rate	- 83.7% true positive rate (TPR)	- Braincap with EEG sensors - Bluetooth - 600 MHz processor
[17]	- develop a low-cost SWM DDD system suitable in real-world	- SWM, EEG, EOG, and PERCLOS - SVM	- 87.9% overall accuracy	- low-cost accelerometer - electrodes - camera
[47]	- Develop a wearable DDD system	- EOG - Sliding Window technique - Autoregressive Integrated Moving Average	- 0.5 seconds ahead of time alert rate	- EOG sensors - Arduino Uno - Android smartphone - HC-06 Bluetooth module
[63]	- develop an EOG classifier that can automatically detect microsleep	- EOG - 256 Hz sampling frequency - Sliding Window technique	- 57% precision - 93% recall	- EOG electrodes
[58]	- Detecting vehicles lane deviations using SWM	- SWM - Exponential Weighted Moving Average (EWMA) - Lane departure	- 91.24% accuracy	- accelerometer -

IV. METHODOLOGY

This section presents the system design details and its experimental setup. This design entails several machine learning models (which are used for drowsiness classification), alongside their evaluation measures. The machine learning models were evaluated in terms of their accuracy, sensitivity, specificity, false alarm rate, and miss rate. In addition, this section encompasses the data collection, data preprocessing, and feature selection approaches. These include a face and eye-state detection model and the calculation of the percentage of eyelid closure (PERCLOS), blink frequency (BF), and maximum closure duration (MCD) as the selected features.

A. System Design

As shown in Fig. 6, the operational design proposes a model following the conventional machine learning process. From this design, the first step is to acquire and preprocess the required data to be used for learning. This data was collected from the NTHU computer vision lab and preprocessed using several video and image processing techniques to detect the driver's eye states. The next step is to extract the targeted features, (from the preprocessed data) which are going to be used as the actual inputs for the learning process. The features extraction process was used to achieve this. This process helps in reducing the dimensionality of the raw inputs (i.e. each video frame pixels), and also in selecting meaningful variables through a combination of these raw inputs. Then, the drowsiness classification process was used to classify the driver's state into either an awake or drowsy state. This process utilizes several machine learning classification models. The result of these models is then evaluated for their accuracy, sensitivity, specificity, false alarm rate, and miss rate in the performance evaluation phase.

B. Dataset

The dataset used for this experiment was a driver drowsiness detection video dataset provided by the National Tsing Hua University (NTHU) Computer Vision Lab. The description of the dataset is given in Table V. This dataset consists of video data from both male and female drivers with various facial characteristics, different ethnicities, and from 5 different scenarios. The videos are in 640x480 pixels, 15/30 frames per second (fps) AVI format without sound. They were taken in real and varying illumination conditions. In addition to the video data, labels for each video frame were also provided whereby each frame was labeled with either a drowsy or a non-drowsy status.

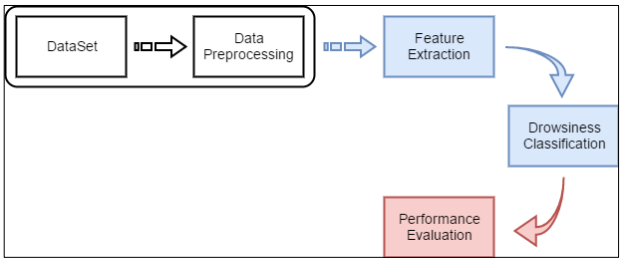

Fig. 6. Operational Design.

TABLE. V. NTHU DATASET DESCRIPTION [64]

Dataset Category	**Description**
Training set	18 subjects with each subject having scenarios that contain each video type separately
Evaluation set	4 subjects with each subject having scenarios that combine all video types into one video
Scenario	**Description**
NoGlasses	Category for 30 frames per second videos and their respective labels
Glasses	
Sunglasses	
Night-NoGlasses	Category for 15 frames per second videos and their respective labels
Night-Glasses	
Driver's Behaviors	**Description**
Yawning	The driver opens his mouth wide due to tiredness
Nodding	The driver's head falls forward when drowsy or asleep
Looking aside	The driver turns his head left and right
Talking and laughing	The driver is talking or laughing while driving
Sleepy-eyes	The driver closes his eyes due to drowsiness while driving
Drowsy	The driver looks sleepy and lethargic (including nodding, slowly blinking and yawning)
Stillness	The driver drives normally
Videos	**Description**
yawning.avi	The video includes yawning behaviors
slowBlinkWithNodding.avi	The video includes sleepy-eyes and nodding behaviors
sleepyCombination.avi	The video includes a combination of drowsy behaviors, e.g. sleepy-eyes, yawning, nodding
nonsleepyCombination.avi	The videos include a combination of non-drowsy behaviors, e.g. laughing, talking, looking aside
Labels	**Description**
drowsiness.txt	0 for Stillness and 1 for Drowsy
head.txt	0 for Stillness, 1 for Nodding and 2 for Looking aside
mouth.txt	0 for Stillness, 1 for Yawning, and 2 for Talking or Laughing
eye.txt	0 for Stillness and 1 for Sleepy-eyes

C. Data Preprocessing

The raw data currently at hand is a 640x480 pixel 15/30 fps video collection and each frame's respective drowsiness annotation. If this data were to be used as it is, proposed machine learning classifiers would have 307,200 inputs/dimension values for each sample. This would have been very computationally expensive with a downside of defying the project aim seeking a low-cost solution, in the first place. Also, from the dataset, only data from 10 subjects in the training set were utilized for training while the whole evaluation set was used for the evaluation process. This totals to 192412 frames (1 hour, 46 minutes, 53 seconds). Thus, the dimension of the classifiers' input has to be reduced. This is what the preprocessing stage aims to achieve.

To reduce the input dimension, eye pupil detection is first performed on each frame by tracking the driver's face then eyes. This reduced the 307,200 inputs to just one value depicting the eye states. Then the eye state data was segmented for each video into a 4 secs segment collection. What this implies is that a 3 min video (i.e. 180 seconds) would have 45 segments, and each segment would contain 120 values, if 30 fps was used. The 4 secs segments are defined as the period (T) threshold and where drowsiness features are extracted from. The 4 secs time frame was selected because that duration is sufficient for experiencing a serious drowsiness damage [16]. And finally, the eye state data is normalized into an open or closed state because of the noises experienced and the capacity of the pupil eye detection model. These processes are further explained in the next sub-sections.

1) Eye pupil detection: The eye pupil detection model takes as input every video frame from the dataset. Then it converts this frame into a gray image, where several image processing operations are performed on it. Adaptive Histogram Equalization (AHE), Adaptive Thresholding, Morphological Transformations, face and eye detection using Haar Cascades, and Contours detection were the operations performed on each frame.

AHE was used to improve the contrast of the gray image. This was required to brighten the night video sets, and also to normalize the contrast of some of the daytime videos which were too light for detecting the driver's face or eyes. Then the driver's face and eyes were tracked using Intel's Haar face and eye cascades. However, only if the driver's face gets detected, the eyes can be tracked (within the detected face region.) This process can be visualized in Fig. 7.

Upon detecting the eye(s), adaptive thresholding was employed to binarize the image for the morphological operations. Erosion and Dilation are the basic morphological operations. Erosion erodes away the white (1) region in the image while dilation increases the white region. For this model, Closing (which is dilation followed by erosion) is performed, then Erosion, and finally Opening (which is erosion followed by dilation) on the binarized eye(s). The Opening was useful for removing noises (scanty white pixels) in the eye image, and closing was used for closing small black points in the image. Then the eye pupil is detected by finding the area with the most concentrated black pixels (which is the eye pupil). This is defined as finding contours (continuous points having the same color or intensity) in OpenCV-Python documentation [65].

As shown in Fig. 7, the outputs can either be 0, 0.5, 0.75, or 1. The output is 0 if the face was detected but the eyes were not detected, or if the eyes were detected but the pupils were not detected. Also, the output is 0.5 if the face was not detected. This holds a value because detecting the face can be impeded by several behaviors such as nodding or looking aside, which are behaviors that are present in the dataset. And finally, the output is 0.75 if only one eye pupil is detected; otherwise, the value of the output is 1. A visualization of how the result looks like is shown in Fig. 8. From this figure, potential drowsiness measures can be identified, which can be exploited.

2) Data segmentation: The eye state data from the previous section and their associated labels were segmented into 4 secs segments before any further preprocessing. The 4 secs segment here is defined as 120 frames, which imply 120 eye states per segment. The 120 frames depict 4 secs because all the videos were later treated as 30 fps so as to enforce consistency in subsequent phases. Also, it is important to recall that every video has four associated label-files (drowsiness.txt, eye.txt, head.txt, and mouth.txt), thus every eye state segment also has four associated label-segments i.e. 480 labels for each eye state segment.

3) Preprocessed data normalization: Several causes, in addition to the presence of noise in the eye state data could be identified in the eye pupil detection section. Also, since only whether the eye is open or closed is tracked, the data has to be either 0 (drowsy) or 1 (awake). To achieve that, the head label of each eye state segment is used and converted the label from 1 (drowsy) to 0 and from 2 (looking aside) to 1. Then the remaining 0.75 values were converted to 1, and the 0.5s were converted to 1 or 0 depending on the statistical mode of the values 1 and 0 in the segment. The result of this process is visualized in Fig. 9.

4) Labels combination: As of now, each eye state segment is associated with four separate label segments, i.e., each eye state has four labels (drowsiness, eye, head, and mouth), and each of these labels could hold a different value. For example, head and mouth labels can contain a value 2 whereby drowsiness and eyes are just 0 and 1. Thus, these labels need to be aggregated into a single value depicting the drowsy state. To achieve this, all head and mouth labels were first converted with a value of 2 to 0 as these labels represent looking away and talking or laughing, respectively (both of which indicate awake states). Then, the average of the four labels was computed and binarized with a threshold of 0.25, i.e., everything greater than 0.25 is converted to 1 and 0 otherwise.

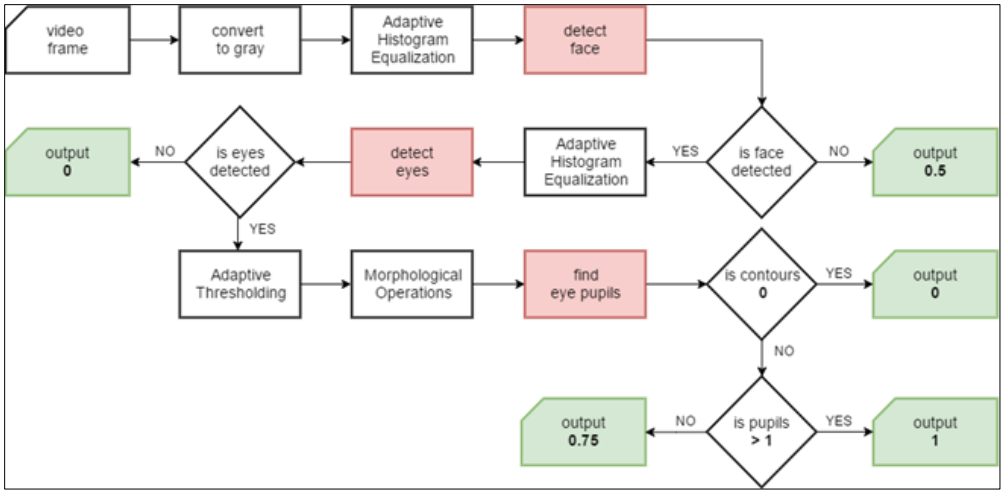

Fig. 7. Eye Pupil Detection Model.

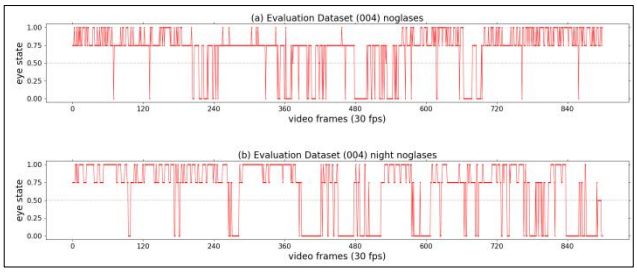

Fig. 8. Evaluation Dataset (004 Subject) Eye State.

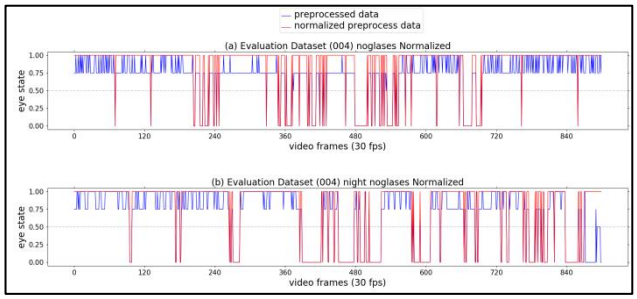

Fig. 9. Evaluation Dataset (004 Subject) Normalized Eye State.

D. Features Extraction

From the normalized eye state data, three features were extracted. This means that the features were calculated in every 4 secs within the video frame. The features calculated are the percentages of eyelid closure (PERCLOS), blink frequency (BF), and maximum closure duration (MCD). The calculation of these features is illustrated in Fig. 10.

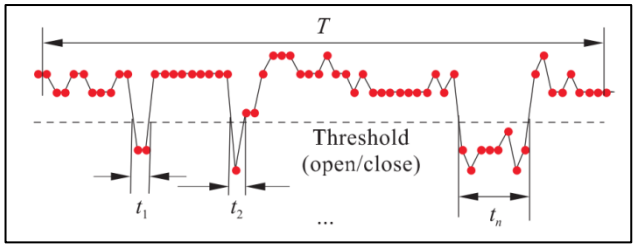

Fig. 10. PERCLOS, BF, and MCD Features Definition [15].

$$PERCLOS = (\frac{t1+t2+\cdots t_n}{T}) \times 100 \quad (1)$$

$$BF = \frac{n}{T} \quad (2)$$

$$MCD = Max(t1, t2, \ldots, t_n) \quad (3)$$

$$where\ T = 120$$

1) Features Standardization: The next and final process after extracting the features was to scale the data so that their range is standardized. This process is required because the machine learning models calculate the distance between two samples using the Euclidean distance at some point in the learning process. Thus, if one feature has a broad range of values than the others, then the distance calculation would be greatly influenced by that feature. And for this data, the features were of the following range: 0 to 100 for PERCLOS because it's a percentage, 0 to 40 for BF, and MCD is 0 to 120 because the length of each data is 120, which is also the maximum amount of time a driver can have his/her eyes closed in a segment. These values indicate BF would not contribute much in the learning process.

There are two popular techniques for normalizing features in machine learning: Min-Max normalization (or rescaling), and Z-score normalization (or standardization). Min-Max rescales the features in the range [0, 1] or [-1, 1], while standardization rescales the features to have zero mean and a unit-variance. For this research, standardization was chosen because it is the most widely employed normalization technique for the range of machine learning algorithms used [66]. The equation for calculating this is shown below:

$$standardization\ \hat{x} = \frac{x - \bar{x}}{\sigma} \quad (4)$$

E. Drowsiness Classification

According to the DDD literature, most researchers usually scope their drowsiness classification to either an SVM or ANN machine learning model. This is logical as these two algorithms excel in high dimension, multi-class, and nonlinear classification problems. However, with a rigid data

preprocessing in place (as in this system), the capabilities of other algorithms can also be explored. Due to this, evaluating several KNN and logistic regression models was considered in the research. Also, the problem at hand is the binary classification problem. This is because the provided labels only identify a drowsy state (1) and an awake state (0).

1) K-Nearest Neighbors (KNN) Models: The KNN algorithm is one of the simplest and popular machine learning algorithms. This algorithm finds the nearest neighbors for a particular point in the sample space and (in a classification problem) then returns the class with the majority vote as the predicted output. For this research, 10 KNN models were designed with varying k values and used them for the classification problem. The details of this design are shown in Table VI.

$$Euclidean\ distance = \sqrt{\sum_{i=1}^{k}(x_i - y_i)^2} \quad (5)$$

2) Support Vectors Machine (SVM) Models: SVM is an algorithm that tries to find the optimal hyperplane that best separates data in an n-dimensional space. The terms optimal and best here indicate a hyperplane with the maximum margin from the support vectors. The support vectors are the points used to define the supporting hyperplane, which serve as the boundaries for the actual hyperplane. In order to find the optimal hyperplane, a kernel function is used to compute the similarity between other points and the support vectors, which is then further used to categorize the data points. The kernel functions extend SVM capability to higher dimensional spaces which thus makes it an important component in the algorithm. To exploit this capability, four are compared in Table VII.

$$linear: \langle x, \acute{x} \rangle \quad (6)$$

$$polinomial: (\gamma \langle x, \acute{x} \rangle + r)^d \quad (7)$$

$$RBF: (-\gamma \|x - \acute{x}\|^2) \quad (8)$$

$$sigmoid: (tanh(\gamma \langle x, \acute{x} \rangle + r)) \quad (9)$$

$$where: \gamma = gamma, d = degree, and\ r = kernel\ projection$$

TABLE. VI. KNN MODEL DESCRIPTION

Property	Description
k value	$k \in \{3, 5, 7, 9, 11, 13, 15, 21, 31, 41\}$
Distance metrics	Euclidean distance

TABLE. VII. SVM MODELS DESCRIPTION

Property	Description
Kernel function K	$K(x, \acute{x}) \in \{linear, RBF, polynomial, sigmoid\}$
Distance metrics	Euclidean distance

3) Logistic Regression Models: Logistic Regression is a machine learning algorithm used for finding the best fitting boundary in a data. Unlike the name stipulates, this algorithm is used for binary classification. However, in order to evaluate its classification capability on the data, 6 different models were designed focusing on the algorithm's optimizer for minimizing its loss function. The structure of this design is detailed in Table VIII.

4) Artificial Neural Networks (ANN) Models: The artificial neural network is a model motivated by the biological structure of the human brain. This model enables the definition of neurons and their categorization into several layers. The input and output layers are the basic building blocks of an ANN model. However, if an ANN model contains just these two layers, it is no more different than a logistic or softmax regression model (depending on the output layer). ANN starts to become distinctive with the inclusion of hidden layers in the neural network. With this structure at hand, shown in Fig. 11, several models can be developed because different hidden layers, number of neurons, activation function, loss optimization function, and learning algorithm can be employed.

However, for this research, a 3 hidden layer neural network was created, with softmax being used as the activation function in the last hidden layer. Two models were developed from this layer structure with a [10, 50, 20] and [3, 27, 9] hidden neurons per hidden layer. For evaluation purposes, 6 optimization functions for minimizing loss were also applied alongside the hidden layer structure described previously, thus making a total of 12 models. Details about the models are displayed in Table IX.

TABLE. VIII. LOGISTIC REGRESSION MODELS DESCRIPTION

Property	Description
Optimizer	$\varphi(x) \in \{GradientDescent, Momentum, Adagrad, Adadelta, RMSprop, Adam\}$
Learning rate	$lr \in \{0.01, 0.01, 0.01, 1.0, 0.0001\}$ for each optimizer respectively

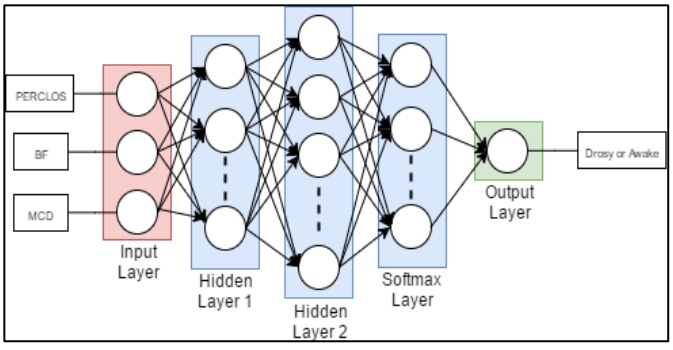

Fig. 11. ANN with 3 Hidden Model.

TABLE. IX. ANN MODELS DESCRIPTION

Property	Description
Optimizer	$\varphi(x) \in \{GradientDescent, Momentum, Adagrad, Adadelta, RMSprop, Adam\}$
Learning rate	$lr \in \{0.2, 0.01, 0.1, 1.0, 0.0001\}$ for each optimizer respectively
Hidden layers and number of neurons	3 hidden layers with [10, 50, 20] and [3, 27, 9] for each optimizer.

F. Performance Evaluation

The final stage of the operational design is to evaluate the performance of the classification models used during the experiment. To do this, the conventional confusion matrix was used to generate the positive and negative prediction scores of each model and then deduct several performance measures from those scores. Details about the confusion matrix and the performance measures targeted are described in the next two sections. In addition to the confusion matrix performance measures, a 10-fold cross validation will also be performed on the KNN and SVM models.

1) Performance Measures: The confusion matrix is a contingency table used in machine learning for visualizing the raw performance of an algorithm. As shown in Table X, this matrix stipulates four scores which are true positive (TP), true negative (FP), false positive (FP), and false negative (FN). The TP score depicts where the classifier correctly predicted a 1 or a truth value. TN, however, indicates where a 0 or false value was correctly predicted. The total of these two scores gives all the classifier's correct predictions, from which the accuracy of the model can be calculated. The FP and FN values, on the other hand, provide wrong predictions, from which the model's bad characteristics are found out in specific instances.

From the confusion matrix above, at least 9 performance metrics can be computed for the models. However, this paper would focus on just 5 of these measures. These metrics include accuracy, sensitivity (true positive rate), miss rate (false negative rate), false alarm rate (false positive rate), and specificity (true negative rate).

a) Accuracy: Accuracy is the basic performance measure for any model or system. The accuracy of a model depicts how close the predicted value is to the actual. In this context, this is how correctly the models predict a drowsy or awake state. The formula for calculating the models' accuracy is shown below:

$$accuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad (10)$$

TABLE. X. CONFUSION MATRIX

	Prediction	
Actual	True Positive (TP)	False Negative (FN) (type II errors | miss)
	False Positive (FP) (type I error | false alarm)	True Negative (TN)

b) Sensitivity and Miss Rate: Sensitivity measures the rate of positive prediction that is truly positive prediction. In other words, it refers to the proportion of predicted drowsiness states which may actually be drowsy. Furthermore, the complement of sensitivity is the miss rate. This is the proportion of actual drowsy states being predicted as awake states. In safety context, the miss rate is very crucial. In the coming section it may be observed that equal significance will be given to miss rate and accuracy when one attempts to determine the performance of the model. The formula below calculates the sensitivity and miss rate.

$$sensitivity = \frac{TP}{TP+FN} \quad (11)$$

$$miss\ rate = 1 - sensitivity \quad (12)$$

c) Specificity and False Alarm Rate: Like sensitivity and miss rate, specificity and false alarm rate measures the degree of negative predictions that are correctly and wrongly predicted. From the false alarm rate, the amount of distraction or discomfort of an actual system can be detected and mitigated. The formula for these two measures is stipulated below.

$$sepcificity = \frac{TN}{TN+FP} \quad (13)$$

$$false\ alarm\ rate = 1 - specificity \quad (14)$$

d) Cross Validation: As stated above, a 10-fold cross validation is performed on the KNN and SVM models. This is to confirm the generalization rate of these models so as to avoid overfitting. The cross validation was not performed on the logistic regression and ANN models because these models are very computationally intensive, thus a cross validation might consume significant time. And also, because the tensorflow library is used, it provides the capability to configure the number of steps for training and testing before converging; hence, it is possible to train or test for a long period of time before generating an output.

V. RESULTS AND DISCUSSION

The result of the standardized extracted features is shown in Fig. 12. As seen in the diagonal figures, the PERCLOS and MCD distribution explicitly depict the drowsiness states. This implies high PERCLOS and MCD should predict a drowsy state while their low values should predict an awake state. For BF, there is not much distinction between the awake and drowsy states. This is, however, expected because in the real-world, slow, medium, or fast blinks have an equal probability of being a drowsy or an awake state.

Finally, the correlation of each feature is also displayed in Table XI. These values and Fig. 12 indicate that BF has weak correlations with other features, with almost no correlation with PERCLOS. Again, putting this in a real-world context, the driver's eyes could be closed for a long period of time within one to many blinks. Conversely, PERCLOS and MCD tend to have a strong positive correlation. This is because both features increase together. However, the scatters in the middle imply they do not decrease together. Sparse MCD values would total to a high PERCLOS.

TABLE. XI. CORRELATION BETWEEN FEATURES

Features	PC and BF	PC and MCD	BF and MCD
Correlation	-0.1709	0.8637	-0.4376

In this section, the performance result is presented for each model under their respective machine learning algorithm. A table will show these results and also accompany it with two figures visualizing the results based on two different comparison approaches. The first figure focuses on generic evaluation measures (like accuracy, sensitivity, and specificity) found in almost every machine learning analysis while the other figure focuses on measures (like miss rate and false alarm rate) that are critical and specific to safety contexts. Also, for evaluation, a benchmark of 70% accuracy and 15% miss rate is defined to determine how the good model should be.

A. K-Nearest Neighbors (KNN) Model Results

As seen in Table XII, all the models yielded varying results. However, they tend to have an average accuracy of 70.67 with k = 3 and k = 31 providing the least and best accuracy respectively. This can be further conceived by looking at Fig. 13, where it depicts that the accuracies increase as the k value increases, even though there were slight decreases when k = 15 and k = 41. This increment correlation can be justified because the models with a higher number of neighbors have more votes of the majority to aggregate from. Although, this can also mean overfitting, the notion is nullified by performing a 10-fold cross validation (CV) on the models. And as seen, the CV accuracies were very close to the original accuracies. This proves no overfitting occurred.

The model's sensitivity and specificity performance is shown in Fig. 13. These two metrics were very crucial in calculating the miss rate and false alarm rate. These two measures must be as high as possible so as to get low miss rate and false alarm rate values. The simulation reveals that k = 31 has the highest sensitivity value which also implies, it has the lowest miss rate. This is convenient as this model had the best accuracy even though having high accuracy does not really signify having a high sensitivity or low miss rate. This is further asserted as this model (k = 31) does not have the best specificity and false alarm rate.

Fig. 14 compares the KNN model's miss rate and false alarm rate. From this figure, the miss rate and false alarm rate seems to decrease as the value of k increases. The best miss rates and false alarm rates were achieved at k=31 and k=21, respectively. Without this variation, k=31 would have been considered as a flawless model for the KNN algorithm. However, this is still tolerable as false alarm has a minimal safety effect on the driver. Thus, the best KNN model is when k=31.

B. Support Vector Machine (SVM) Model Results

For SVM evaluation, several kernel functions were compared. These functions transform the similarity computation between the input points and selected support vectors into different dimensions. The result of this experiment is shown in Table XIII. Like the KNN models, a 10-fold CV was performed to denounce overfitting. From the results, the sparseness of features is inferred when the linear model obtained higher accuracies than most of the non-linear models. This depicts the linearity between the features and the drowsiness states. This is further confirmed in the next section with logistic regression (a linear model), whereby the accuracies are between 69% and 70%.

The RBF model, however, performed better than the linear model. This is because the linear kernel is a special case of RBF [67] and with the RBF has the capability to fit cases (nonlinear categories), which the linear kernel cannot. The CV accuracies also showed no overfitting occurrence, except for the sigmoid function with a significant of 4% difference. Fig. 15 depicts the performance of different SVM models, briefly giving a bird's eye-view of their accuracies CV accuracies, sensitivities, and specificities.

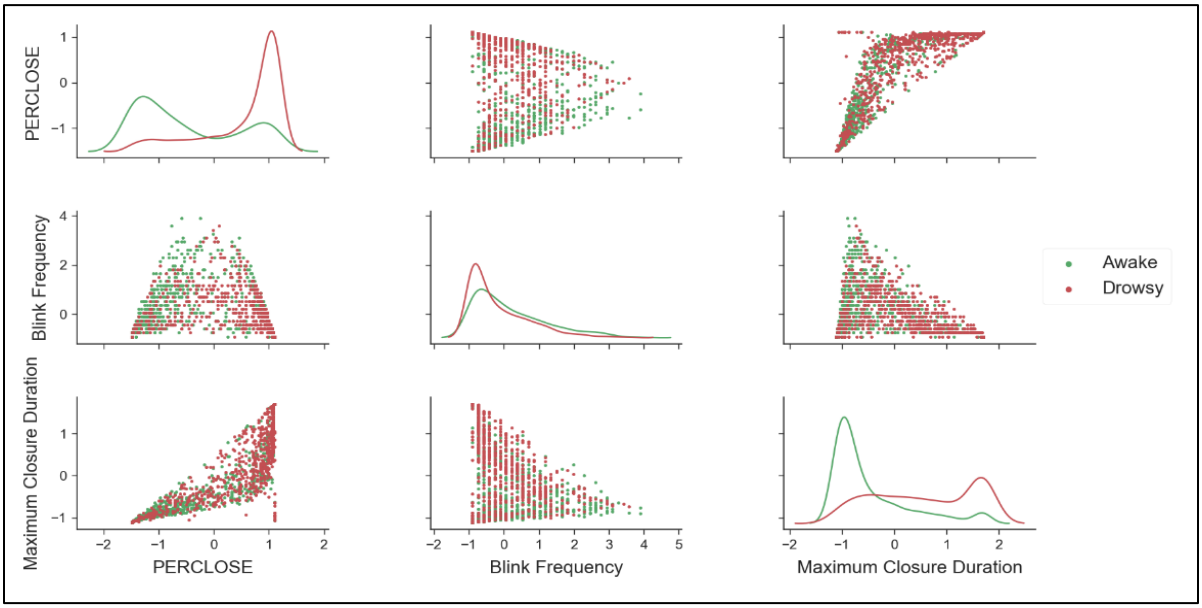

Fig. 12. Standardized Extracted Features.

TABLE. XII. KNN PERFORMANCE EVALUATION RESULTS

K value	Accuracy	CV accuracy	Sensitivity	Specificity	Miss rate	False alarm rate
3	67.78	64.11	76.67	55.81	23.33	44.2
5	69.38	67.46	79.17	56.18	20.83	43.82
7	69.06	68.42	79.17	55.43	20.83	44.57
9	70.81	68.42	82.22	55.43	17.78	44.57
11	71.29	68.90	82.5	56.18	17.5	43.82
13	71.45	69.06	82.78	56.18	17.22	43.82
15	70.97	68.10	82.5	55.43	17.5	44.57
21	71.93	69.06	81.94	58.47	18.06	41.57
31	72.25	70.33	83.33	57.30	16.67	42.7
41	71.77	71.29	81.94	58.05	18.06	41.95
Average	**70.67**	**68.52**	**81.22**	**56.45**	**18.78**	**43.56**

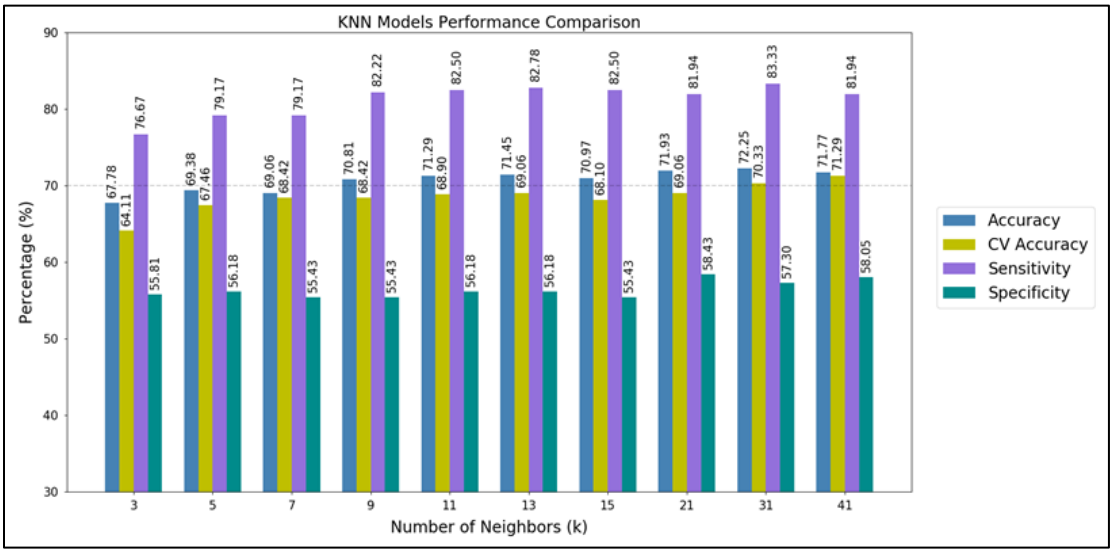

Fig. 13. KNN Models, Accuracy, CV Accuracy, Sensitivity, and Specificity.

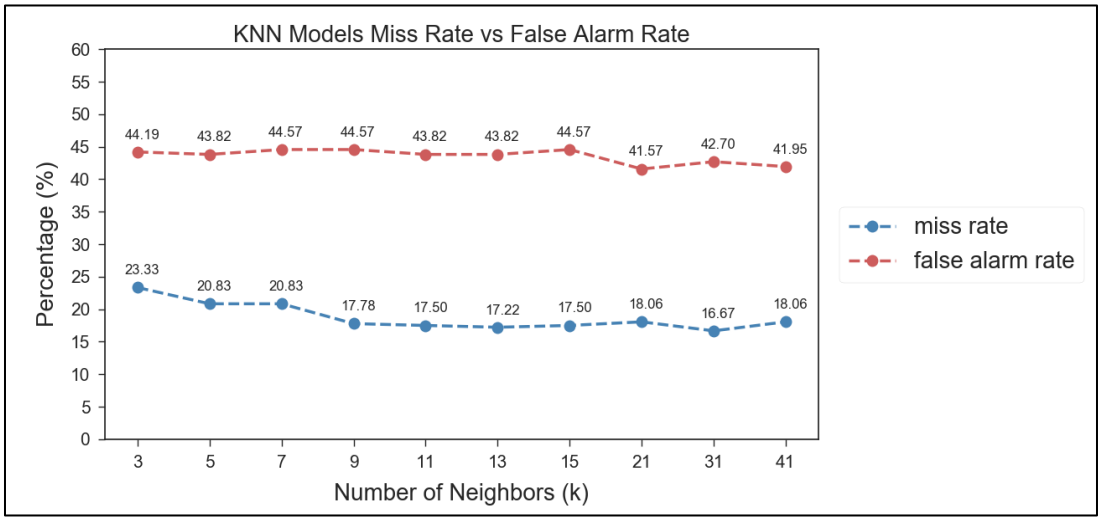

Fig. 14. KNN Models Miss Rate and False Alarm Rate.

TABLE. XIII. SVM PERFORMANCE EVALUATION RESULTS

Kernel function	Accuracy	CV accuracy	Sensitivity	Specificity	Miss rate	False alarm rate
Linear	69.86	68.42	78.61	58.05	21.39	41.95
RBF	70.66	69.7	80.56	57.30	19.44	42.7
Sigmoid	69.22	65.23	81.34	52.81	18.61	47.19
Polynomial	68.9	68.58	86.94	44.57	13.06	55.43
Average	**69.66**	**67.98**	**81.86**	**53.18**	**18.13**	**46.82**

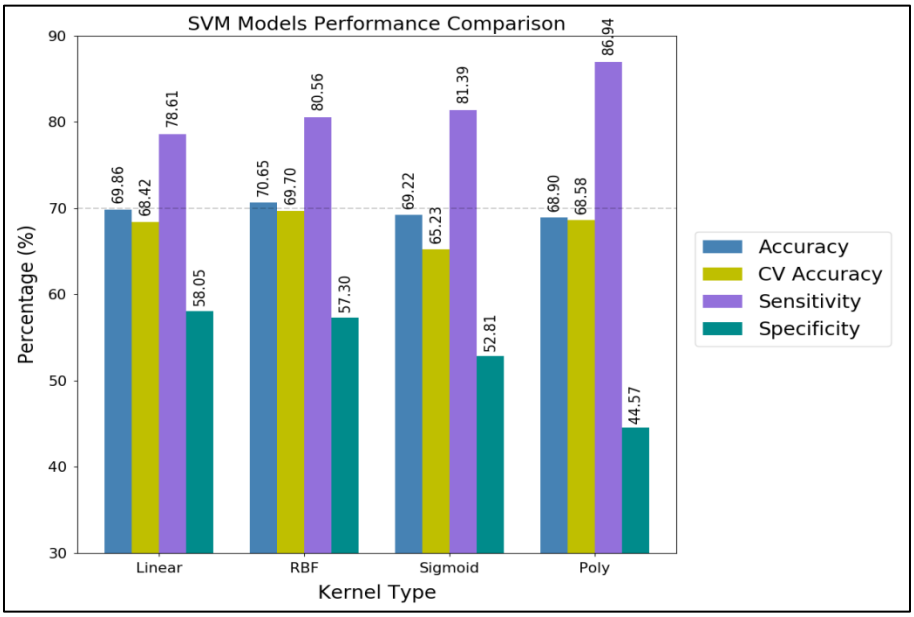

Fig. 15. SVM Models, Accuracy, CV Accuracy, Sensitivity, and Specificity.

In contrast to accuracy and specificity, the nonlinear kernels excelled at predicting the correct drowsy state (sensitivity) than the linear kernel. Thus, this means they have lower miss rate values. This is shown in Fig. 16, where the polynomial kernel had the lowest miss rate value. This is true because the strength of the polynomial kernel comes from it having more hyperparameters than the other kernels which thus increases its complexity. However, the RBF model was selected as the best model because it had the best accuracy, false alarm rate, and a considerable miss rate. The polynomial model on the other hand, had the worst accuracy and false alarm rate.

C. Logistic Regression Model Results

The logistic regression algorithm is a linear classifier for binary classification (awake or drowsy in this case). This algorithm tries to find the optimal weight required in fitting the best line through the data. In order to achieve this weight, an optimizer is required to minimize the loss function so that the predicted values are closer to their actual counterpart. Several models were developed to compare the result of different optimizers. The optimizers chosen were a category of optimizers developed as improvements to the popular gradient descent optimizer. Also, in order to achieve this, each optimizer's parameter was tuned so as to attain their possible best result. The parameter values used are stipulated in Table XIV.

Table XIV, Fig. 17 and Fig. 18 show the result of each optimizer. As seen in the table and the figures depicted, Adam and gradient descent had the best accuracies. However, with respect to gradient descent, the two other optimizers, with 70% accuracy, are known for their great impovement on gradient descent's learning rate selection [68]. The Adam optimizer also had the best miss rate while RMSProp had the best false alarm rate. This is visualized in Fig. 18, where due to the linearity of the models, a (negative) correlation between the miss rate and false alarm rate was perceived. The Adam optimizer model was thus selected as the best model because this model obtained the best accuracy and miss rate.

D. Artificial Neural Network (ANN) Model Results

The final set of models evaluated was based on the ANN algorithm. The definitions of these models were similar to that of logistic regression, where different loss function optimizers were evaluated. However, since neural networks are being dealt with, two neural nets with 3 hidden layers were created whereby each hidden layer had different number of neurons. The result of this evaluation is shown in Table XV. As seen in this table, most of the models had 70% accuracy, thus signifying superiority to other machine learning algorithms compared with the provided data.

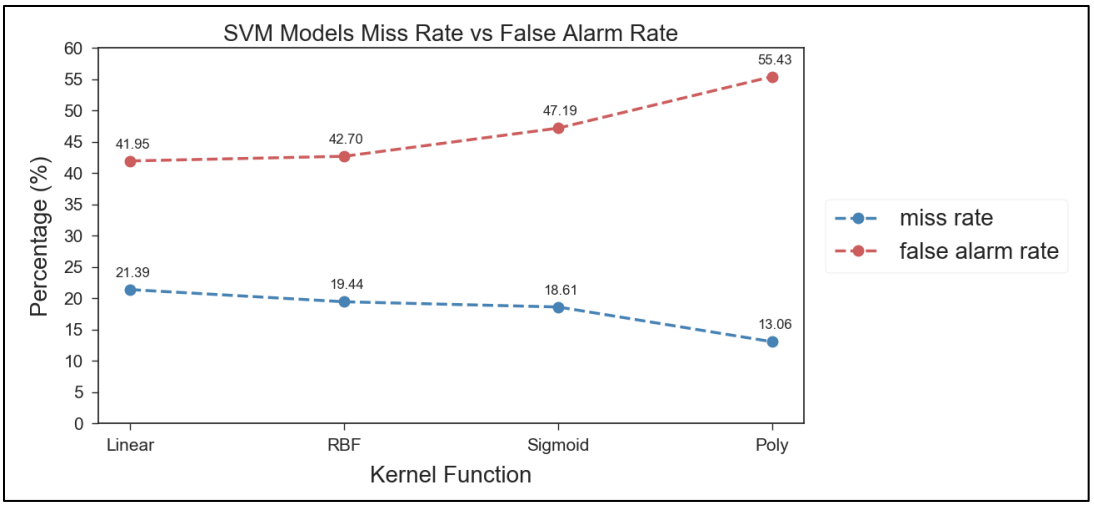

Fig. 16. SVM Models Miss Rate and False Alarm Rate.

TABLE. XIV. LOGISTIC REGRESSION PERFORMANCE EVALUATION RESULTS

Optimizer	**Accuracy**	**Sensitivity**	**Specificity**	**Miss rate**	**False alarm rate**
GradientDescent	70.81	81.11	56.93	18.89	43.07
Momentum	69.70	77.50	59.18	22.50	40.82
Adagrad	70.02	78.06	59.18	21.94	40.82
Adadelta	69.54	76.94	59.55	23.06	40.45
RMSprop	69.22	77.22	58.43	22.76	41.57
Adam	70.81	86.11	50.19	13.89	49.81
Average	**70.02**	**79.49**	**57.24**	**20.51**	**42.76**

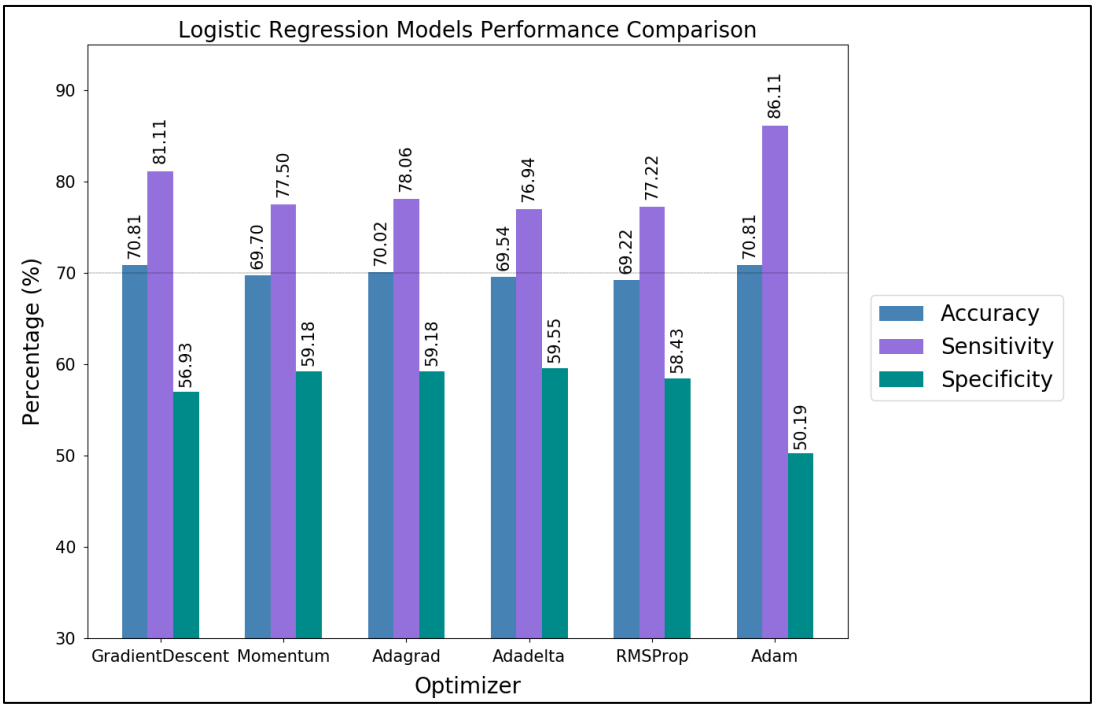

Fig. 17. Logistic Regression Models, Accuracy, Sensitivity, and Specificity.

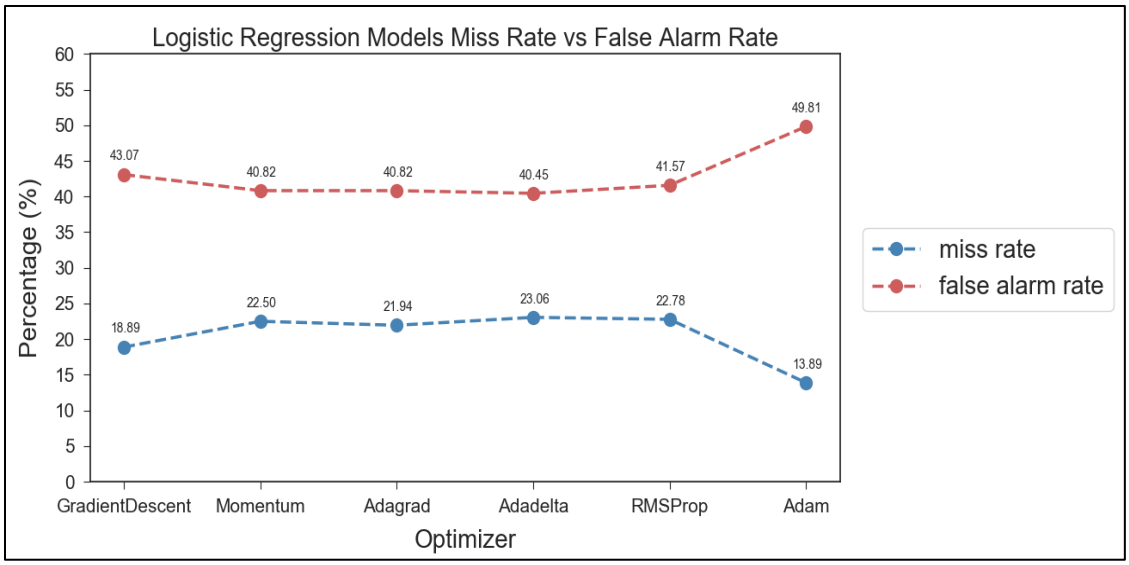

Fig. 18. Logistic Regression Models Miss Rate and False Alarm Rate.

TABLE. XV. ANN PERFORMANCE EVALUATION RESULTS

Optimizer/ Hidden layer	Accuracy	Sensitivity	Specificity	Miss rate	False alarm rate
GradientDescent[10, 50, 20]	71.13	81.67	56.93	18.33	43.07
Momentum[10, 50, 20]	71.45	85.28	52.81	14.72	47.19
Adagrad[10, 50, 20]	70.49	86.67	48.69	13.33	51.31
Adadelta[10, 50, 20]	70.34	86.39	48.69	13.61	51.31
RMSprop[10, 50, 20]	68.9	80.56	53.18	19.44	46.82
Adam[10, 50, 20]	71.61	85	53.56	15	46.44
Average	**70.65**	**85**	**53.56**	**15**	**46.44**
GradientDescent[3, 27, 9]	71.45	85	53.18	15	46.82
Momentum[3, 27, 9]	71.45	85.83	52.06	14.17	47.94
Adagrad[3, 27, 9]	69.7	78.06	58.43	21.94	41.57
Adadelta[3, 27, 9]	71.61	85.56	52.81	14.44	47.19
RMSprop[3, 27, 9]	71.45	85.83	52.06	14.17	47.94
Adam[3, 27, 9]	69.38	78.06	57.68	21.94	42.32
Average	**70.84**	**83.06**	**54.37**	**16.94**	**45.63**

Table XV has been translated to the graph depicted in Fig. 19 showing the comparison of performance measures of different ANN models. The results have been categorized based on the neural network structure. And as seen in the table, the network with 3, 27, and 9 neurons per layer obtained the best accuracy and false alarm rate, while the other network obtained the best miss rate. From this, it is inferred that the number of neurons per layer strongly affects these measures even though enough experimentation hasn't been carried out to generalize which network structure is most effective.

However, regarding the loss function optimizers, Adam and Adadelta attained the best accuracies in the [10, 50, 20] and [3, 27, 9] networks, respectively. The Adam and Adadelta optimizers were able to perform well in these scenarios because they computed adaptive learning rates for the traditional gradient descent parameters [68]. However, the Adadelta was chosen in the neural network [3, 27, 9] as the best model for the ANN algorithm because its miss rate was better than that of Adam's as shown in Fig. 20.

E. Best KNN, SVM, Logistic Regression and ANN Model Comparisons

As shown in Fig. 21, each model has its strengths and weaknesses regarding accuracy, miss rate (compliment of sensitivity), and false alarm rate (compliment of specificity). The KNN model had the best accuracy and false alarm rate while competing with the SVM's false alarm rate. This is expected as KNN is a very good classifier when supplied clean data. However, the SVM model does not perform much compared to other models. This was surprising as SVM is a very strong classifier. This might be due to the parameter settings for the models. Thus, providing better or optimal parameters might improve the SVM performance. Nevertheless, this model had the best false alarm rate.

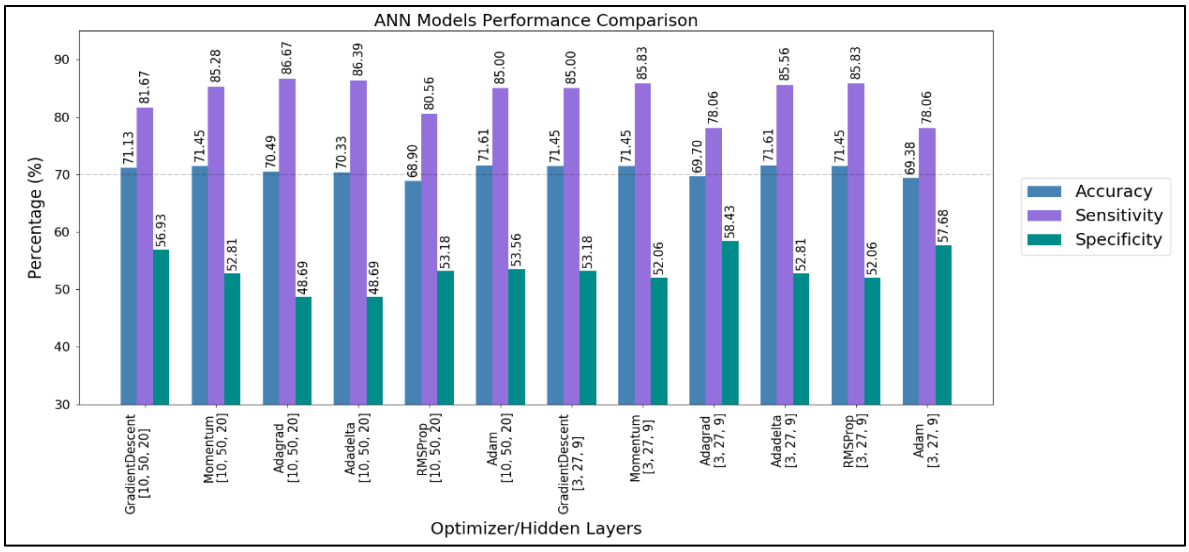

Fig. 19. ANN Models, Accuracy, Sensitivity, and Specificity.

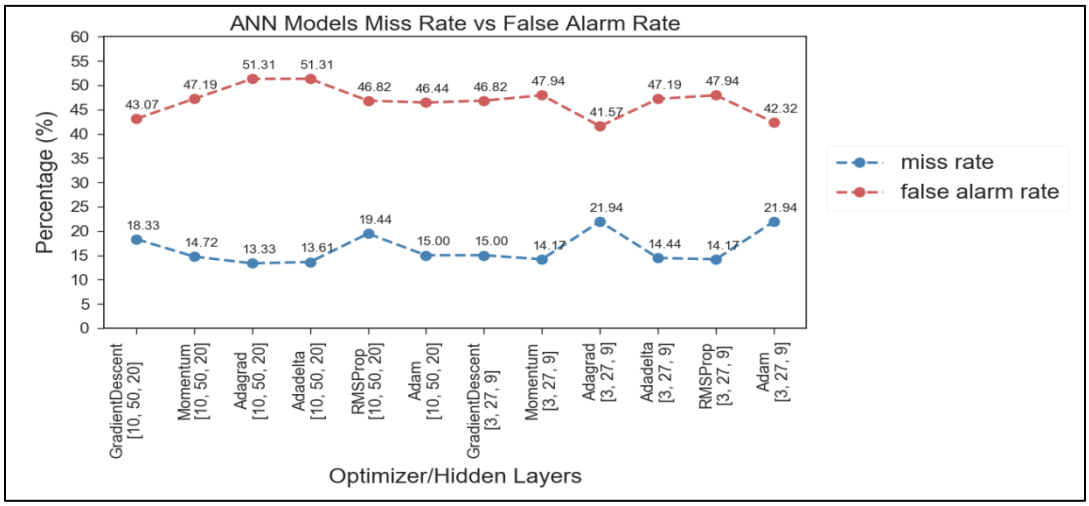

Fig. 20. ANN Models Miss Rate and False Alarm Rate.

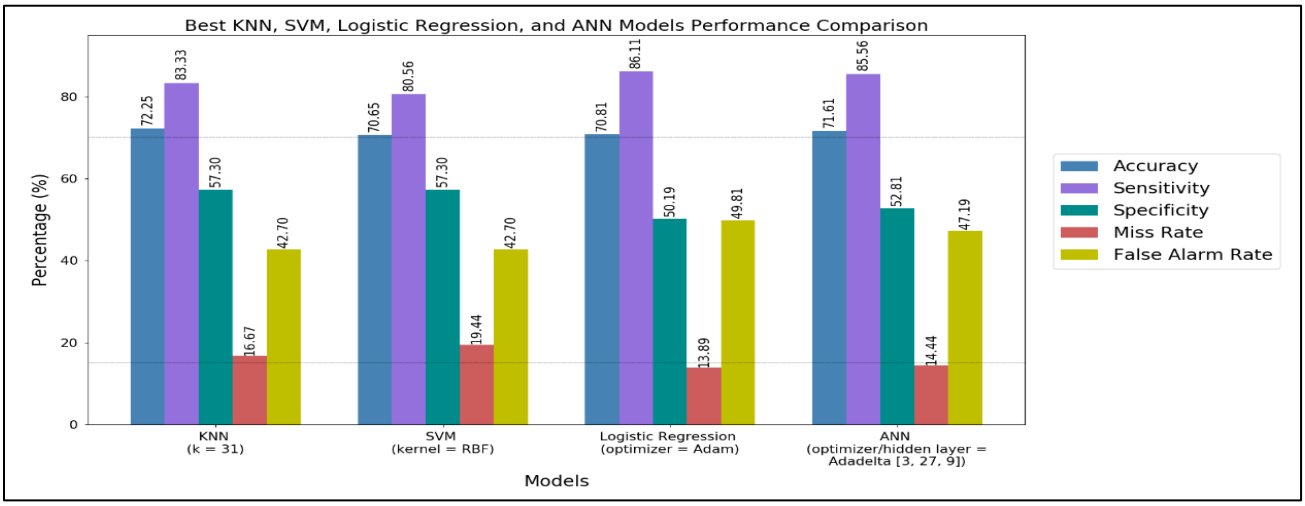

Fig. 21. Best KNN, SVM, Logistic Regression, and ANN Performance.

The logistic regression model had the best miss rate. This capability is very important as drowsy driving is considered a safety problem; thus, missing to classify a drowsy state as the awake state is a critical issue. Comparing this model to the KNN model, the KNN model performed better in all aspects except the miss rate where the logistic regression model surpasses it by 3%, this difference is still tolerable.

The final model is the ANN model. The result of this model can be interpreted to be better than the KNN model depending on the tradeoffs between accuracy and miss rate. However, this model obtained an accuracy of 71.61 and a miss rate of 14.44.

F. Result Benchmark

ANN and KNN results were compared with the paper recommended by the creator of the NTHU dataset. The result of this comparison is shown in Table XVI below. This paper by [69] provided two models using two different fusion strategies: independently-average architecture (IAA) and feature-fused architecture (FFA). And as shown below, the IAA and FFA obtained 73.06 and 70.81 accuracies, respectively. Author in [69] also evaluated the performance of popular multi-class classification algorithm on this dataset in their experiment. Comparing the result of this model and the other algorithms they evaluated with the result of proposed KNN and ANN model, proposed models obtained better accuracies than the latter, except their IAA model which had 73% accuracy.

TABLE. XVI. BENCHMARK RESULT

Researchers	**Accuracy (%)**
Proposed KNN	72.25
Proposed ANN	71.61
DDD-FFA [69]	70.81
DDD-IAA [69]	73.06
AlexNet [70]	62.99
VGG-FaceNet [71]	61.50
FlowImageNet [72]	67.85
LRCN [72]	65.93

VI. FUTURE WORK

As it was evident that the methods proposed in the research were non-intrusive and the results obtained were on par with the benchmarks considered, a real world prototype model will be developed. To start with, a simple prototype using a micro computer, capable of handling computer vision, like raspberry pi paired with a high resolution camera will be developed and tested. The output of the DDD system can be used to expand the research further or can be relayed to a control system of a vehicle to enable actuation based DDD output.

VII. CONCLUSION

This research focused on finding a low-cost and non-intrusive driver drowsiness detection solution which is based on face and eye tracking. To achieve this solution, several kinds of literature works were reviewed to understand the driver drowsiness detection ecosystem. These literature works incited greater interest in this domain because driver drowsiness is considered as a major contributor to road accidents. With this problem at hand, it was discovered that most of the DDD researches, even though they obtained high accuracies, were unable to make it to real-world scenarios. With this research, this paper thus proposes a non-intrusive solution based on tracking the face and eyes of the driver, thus, not requiring any attachment to the driver. A low-cost solution was obtained by performing experimentation on a medium-quality video dataset. The eye pupil detection model and the numerous machine learning models were the contributions to this ecosystem.

However, the accuracy of the system was found to be at most 70-75%. In addition to this, the video feed required complex hardware and processing power, any lag due to which would result in fatal consequences. The video feed must be of high resolution and recorded in well-lit conditions, which may not be the case always in real world scenarios. This could lead to deviations in results. Any glares flashed, most importantly, on the driver's face might cause distractions or involuntary closure of eye lids, giving false alarms to the system. The data set must be acquired from various drivers not belonging to the same family, since genetic similarities can directly affect the specificity of the algorithms.

Although there are several improvements that can be embedded into this research, it is believed that the current result is adequate for deployment into a real system which can be used in the real-world scenario. This research is therefore considered as an inception for DDD ubiquity.

ACKNOWLEDGMENT

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QoS Analysis to Optimize the Indoor Network IEEE 802.11 at UNTELS

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Abstract—This paper arose from the need to improve mobility and connectivity to network users of the Universidad Nacional Tecnológica de Lima Sur and the problems that arise on the quality of services (QoS) such as signal intermittence, high latency, low decibels of received power, low coverage equipment that doesn't support high data transit and exceed the limit of connected users. An analysis is presented for optimization of the IEEE 802.11 wireless QoS in indoor media, the coverage data collected from the different equipment based on reception power measurements made with the Wi-Fi Network Analyzer software, mapping of the ideal approach to new coverage areas and the location of Access Points in areas with high student, administrative and teaching staff of the university through simulations of the coverage of the equipment made with NETSPOT software. The results obtained show that the actual design of the wireless network presents interference by equipment configured in the same transmission channel and adjacent, as well as insufficient coverage of radiated power for indoor environments due to the poor location and choice of models of access points, and to be replaced with Access point with high density characteristics of users connected simultaneously by equipment, suitable for indoor environments with technologies such as MU-MIMO and ARM; the results are shown favorable and optimized.

Keywords—Access point; QoS; coverage; indoor; software

I. INTRODUCTION

Wireless networks are growing rapidly and rapidly due to its great advantage of installation, flexibility and scalability, being the most used 802.11 standard known worldwide by its trade name as Wi-Fi so-called by Interbrand who was hired by the founding members of the Wireless Ethernet Compatibility Alliance [1], now known as Wi-Fi Alliance, the organization that promotes Wi-Fi technology and created a standard of connection with multiple devices that certified the interoperability of equipment under the protocol IEEE 802.11 [2].

The use of this type of network is directly linked to the number of Internet users whose rate of growth influences proportionally. In 2018 the Internet had a number of users of 4,021 million, by contrast, 2019 has to date 4,388 million Internet users, 57% of the world population, representing an increase of 9.1% in 1 year. Also, 52% of Internet users have connected via wireless [3], a figure that shows that the problems that can arise in this type of network configuration would involve more than half of users in the world.

Many problems arise when implementing a network, greater is the case when it is a wireless network, this due to the hostile environment as gauging, temperature, distance and all kinds of natural barriers that faces the signal during the Transmitter/Receiver journey being impossible from the beginning to satisfy the QoS in its entirety and for all cases. [4].

It is becoming more and more difficult to ignore when problems arise to a large extent as a result of not having an adequate design. According to studies carried out in environments with an adequate indoor design (buildings), the best results considering the normalized throughput as an efficiency measure are obtained with a network based on the IEEE 802.11n standard with 78%, while with IEEE 802.11b an efficiency of 17% [5] is obtained, being a very low percentage of signal use even in the best of scenarios (78%).

However, when a cable installation system cannot be used because the environments and conditions do not allow it, Wi-Fi becomes a relevant object of study. In the case of a university where students can access the network more easily From mobile devices, Wi-Fi cannot be ignored despite the many adverse factors that arise.

The present work the objective is to analyze the functioning of the network in order to propose solutions in the parameters of QoS to optimize the use of an indoor Wi-Fi network analyzing the delays, loose packages, jitter and badly routed packages that can damage the data transmission [6], in the case of the Universidad Nacional Tecnologica de Lima Sur (UNTELS the primary purpose is to provide users with a quality of service that meets the minimum standards and highlight the importance of the work in front of current technological needs where a good network connection means to provide better results in academic and work activities where a good network connection means to provide better results in academic and academic activities.

In the related works we can find the publication of the researcher R. Costa in May 2019 [7], where he analyzes how to control in real-time the communications under the same 802.11 standard but in the industrial field where there are essential problems such as those proportional to the installation environment, or the work of Ljiljana Simić in 2017 [8], where he studied the impact of transmission channels to improve performance in high-density indoor networks, and demonstrated that 80 MHz full channels are beneficial only in dense networks with loads of Extremely high traffic.

In the following section, the methodology used, the propagation model in indoor systems, and the main equations for the correct analysis of service quality will be known. Likewise, the b / n configurations of the IEEE 802.11 standard protocol and a quick explanation of the use of the software used, so that each user can apply them at the time of locating the access points and obtain the most efficient possible resource of each equipment. Section III will analyze the results obtained theoretically and those obtained in real-time with the software, considering a new design in case the parameters in dBm are not within the ranges of a good signal.

II. Methodology

For the analysis of the Wi-Fi network must take into account the correct order of data collection and interpretation as a fundamental part of the study, for this a flow of necessary actions must be taken into account.

"Fig. 1" shows the methodology used to analyze whether the actual Wireless QoS network or a new drafting system is better as a starting point, the battery status is the 802.11 standard system and the ITU-R P.1238-9 standard, if the network meets the requirements to obtain a data collection with the software for the power of the Wi-Fi signal, the last step to analyze the results and the verification with the propagation model inside ITU - R P.1238- 9. According to the results, it is possible to determine if it is necessary to apply a new design to optimize the Wireless QoS in the network.

A. Model of Indoor Propagation

Indoor propagation is based on the model of ITU-R Recommendation P.1238-9, updated in 2017, and provides propagation data and prediction method of high importance for the design of indoor and local area radio communication systems in the frequency range 300 MHz to 100 GHz [9].

The basic model is as follows, Eq. 1:

$$Ltotal = 20logf + Nlogd + Lf(n) - 28 \quad (1)$$

Where:

–*N*: power loss coefficient. See Table I.

–*f*: frequency (MHz)

–*d*: separation distance (m) between the transmitting equipment and the receiving terminal (where d > 1 m)

–*Lf*: soil penetration loss factor (dB). See Table II.

–*n*: number of floors between the transmitter and the receiver terminal (n ⩾ 1).

To calculate the reception power, the Friis equation is proposed [10], Eq. 2:

$$Pr = Pt + Gt + Gr - Ltotal \quad (2)$$

Where:

-*Pr*: receiving power (dBm)

-*Pt*: AP transmit power (dBm).

-*Gt*: transmitter antenna gain (dBi)

-*Gr*: receiver antenna gain (dBi)

-*Ltotal*: radio path losses in media indoor (dB)

To find the reception power on mobile devices, the gain and transmission values of the Alcatel-Lucent OmniAccess Stellar AP1101 access point consulted in the datasheet must be taken into account, it is also necessary to measure the distance between both devices and Consider radio path losses.

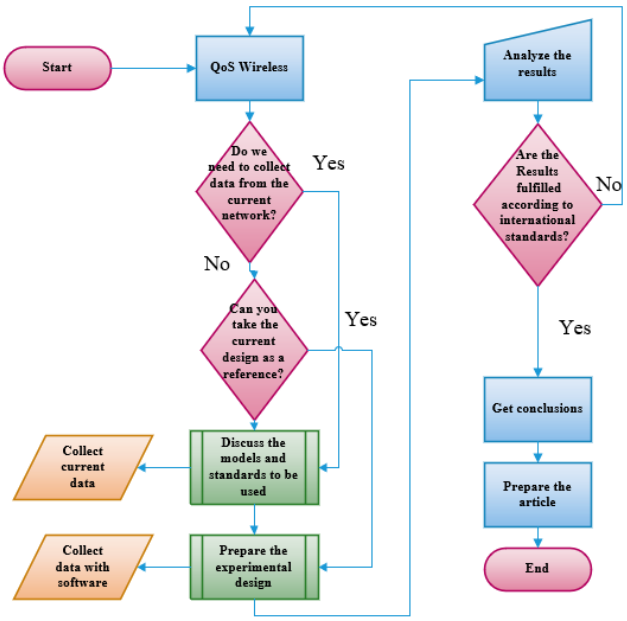

Fig. 1. Flow Diagram of the Methodology.

TABLE. I. Coefficients of Loss of Power, N, for the Calculation of the Loss of Transmission in Interiors. [9]

Frequency	Residential building	Office building	Commercial building
900MHz	-	33	20
2.4GHz	28	30	-
5.2GHz	-	31	-
5.8GHz	-	24	-

TABLE. II. Factors of Loss of Penetration in the SOIL, (DB), being N the Number of Floors Penetrated, for the Calculation of the Loss of Transmission Interiors (N ⩾1) [9]

Frequency	Residential building(dB)	Office building(dB)	Commercial building(dB)
900MHz	-	9 (1 floors) 19 (2 floors) 24 (3 floors)	20
2.4GHz	10 (depart.) 5 (home)	14	-
5.2GHz	13 (depart.) 7 (home)	16 (1 floor)	-
5.8GHz	-	22 (1 floor) 28 (2 floors)	-

B. Areas of Coverage

The equipment that is currently implemented should be analyzed to study its characteristics after reviewing its corresponding datasheet and making a comparison with other equipment of similar or better characteristics that suits the purpose according to capacity and location. To make this discovery of equipment is necessary to have software, in this case, the Wi-Fi Network Analyzer provides the list of access point used by the university, the devices have in their mac address with the following ID: 80:2a:a8, to discover the manufacturer must track the address with the online tool Mac Address Vendor Search or similar.

The manufacturer of the detected Access Point is Ubiquiti Networks Inc. of model Outdoor to 2.4GHz located in the external part of a pavilion to take advantage of the radiation of signal in interior and exterior environments.

Scanning the Access Point models also results in the number of AP's, a distribution of four devices located outside the pavilions.

Fig. 2. Map of the Universidad Nacional Tecnológica de Lima Sur.

The indoor environments to study are:

A: Pavilion of halls of 1 row and 1 hallway

B: Pavilion of halls of 2 rows and 1 hallway

"Fig. 2" shows the map of the university campus indicating administrative offices, library, pavilions and other areas [11].

In-situ measurements of the pavilions provide data for the design of the structural plan in the Autocad 2020 program and to discover the coverage areas, the Wi-Fi Heatmaps software is used, previously loaded the imported plan and making the route through the interior environments connected to the wireless signal to be measured, in this case the Wi-Fi Untels network.

"Fig. 3" shows the heat map generated by the power in dBm of the Ap's and measured with the software in a terminal that has a wireless module of good sensitivity, drawing the map automatically as we move the terminal activated the GPS and varying the intensity of power received, wherein red the quality of signal received is bad, in yellow is regular and in green is good.

C. Density of Users

The study of the density of users is of vital importance when making the design of a Wireless network, according to recommendations raised the number of customers connected to an access point should be limited between 20 and 30 simultaneous users [12].

For carry out the analysis of the density of users, we proceeded to use the tool NetSpot or Wi-Fi Network Analyzer and vary the scanning periods in order to obtain results that show the number of users connected in a routine of the week.

These applications based on multithreaded union, use LAN scanner, in this scanner, every device connected to the local network is shown. Each device exports data such as hostname, IP address, MAC address, type of network security, among others. The software works by sending ARP (Address Resolution Protocol) messages to the broadcast belonging to the target network of the analysis.

D. Problems during Connection

The intermittence in the connection is product of the interference of signals, the biggest problem in the wireless networks, where the level of the problem is proportional in the difference of power of the signals radiated adjacently, that is to say, if two signals transmitted by the same channel, the transmitter that emits smaller power is the most affected by this phenomenon.

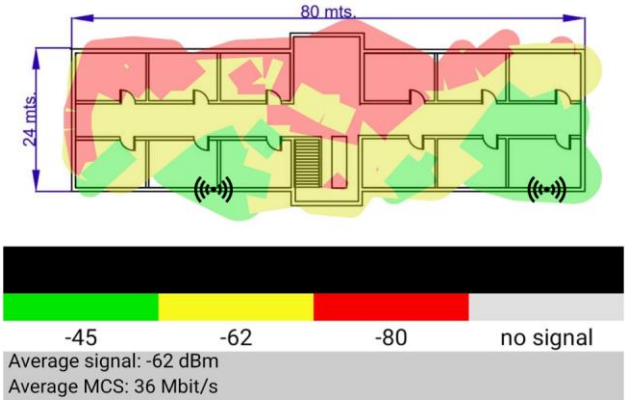

Fig. 3. Heat Map of Pavilion B.

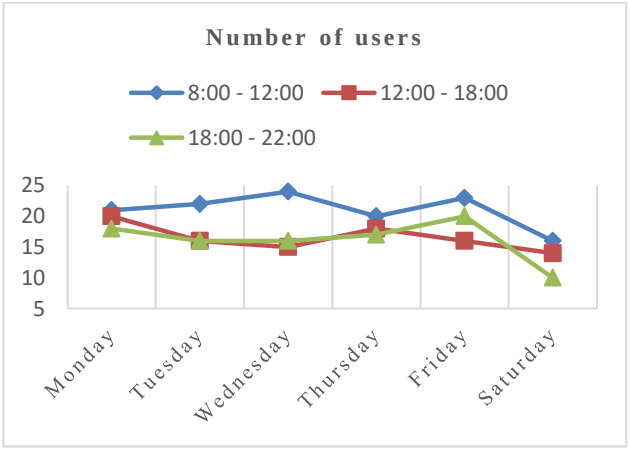

Fig. 4. The Density of users Connected to the Wi-Fi Untels Network.

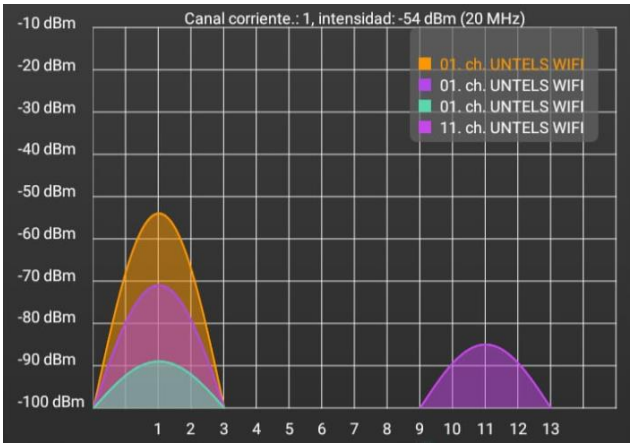

Fig. 5. Diagram of Transmission Channels with Wi-fi Network Analyzer.

With the use of the Wi-Fi Network Analyzer tool, we proceeded to scan the different radiated signals to find signals that are producing interference with each other and filter the results to observe the four access points of the objective of the analysis.

"Fig. 5" shows the transmission channels used with reference to radiated power where it is observed that work with channels 1 and 11 with a center frequency of 2.412 GHz and 2.462 GHz, respectively.

III. Results

To ensure a stable connection, the receiving power, must not be less than -70 dBm. In the study carried out, see "Fig. 3", the radiated signal power of the two access points corresponding to pavilion B cannot cover the broad interior environment of 3 vertical floors, detecting zones where -70dBm are exceeded. Equipment should be replaced by indoor models and two access points placed in the center of each floor of the pavilions, as shown in "Fig. 6" to achieve adequate signal coverage.

The distribution for the new optimized design was done with 2 Alcatel-Lucent OmniAccess Stellar AP1101, for its ability to control the bandwidth assigned to each terminal dual-frequency transmission 2.4GHz and 5GHz and 2x2 MIMO technology, showing favorable results in "Fig. 7", reaching a signal quality higher than -70dBm in almost all indoor environments. The floor structure is homogeneous; therefore, the design will be repeated in each floor and also for pavilion A, which has a smaller area dimension.

The density of connected users in "Fig. 4" reflects a positive comparison with the recommendations referenced in [10], ruling out equipment saturation.

The access points can be configured in such a way that one can automatically choose the channels to work. In the analysis, it was possible to find overlapping frequencies that generate interference and transmission delays between three equipments configured in channel 1; only the fourth access point works optimally on channel 11. This problem can be corrected by changing the configuration of the equipment in different channels, AP1 in channel 1, AP2 in channel 4, AP3 in channel 8 and AP4 in channel 11 or whether to activate the Adaptive Radio Management (ARM) option if the equipment has this technology.

The heat map obtained by software does not offer an error of 0%, in order to obtain a more accurate study; it is compared with the results obtained from the equations presented in the previous section, with values of the measurements made on-site as represented in "Fig. 8".

Table III shows the losses of the radio path in indoor media, these losses depend directly on the places where the equipment will be installed with respect to the structure of the building.

The results obtained from Eq. 1 and 2, at a frequency of 2.4 GHz based on the ITU-R P.1238-9 standard; result in a minimum error of 8.7% and a maximum error of 9.67% with respect to the measured values.

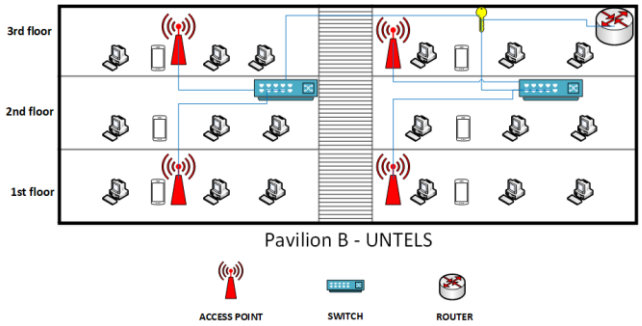

Fig. 6. The Ideal Location of Indoor Equipment.

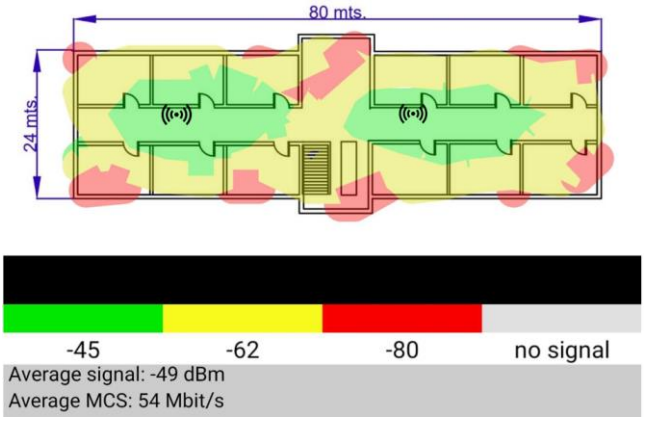

Fig. 7. Diagram of Transmission Channels with Wi-Fi Network Analyzer.

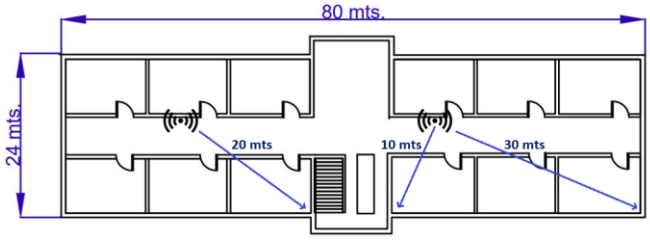

Fig. 8. Distances between the Receiver and Transmitter Equipment.

TABLE. III. RESULTS OF THEORETICAL POWER AND MEASUREMENT

Results with Stellar AP1101			
Loss of radio path (Ltotal):			
ITU-R P.1238-9	10 meters	20 meters	30 meters
	-83.60 dB	-92.64 dB	-97.92 dB
Receiving Power (Pr):			
Friis, Eq. 2	10 meters	25 meters	30 meters
	-63.2 dBm	-72.24 dBm	-77.52 dBm
Measured value	10 meters	25 meters	30 meters
	-57.09 dBm	-65.96 dBm	-70.01 dBm

IV. CONCLUSIONS

Having an optimal quality of service in wireless networks requires good design based on standards and measurements as a fundamental basis for implementation.

The transmission channels when working at 2.4 GHz have very few transmission channels, specifically 14, which is why interference is a complicated factor to correct as discussed in this paper. Currently, the most recent equipment has 5 GHz technology that has 25 transmission channels not overlapped and under the same standard 802.11.

The distribution and choice of transmitting equipment must be designed according to the field of application, another important factor is the capacity, the configuration and design must be done always leaving availability to scale based on the results obtained.

However, this study presents some limitations such as the number of equipment tested, in this case, according to the results, we opted for an equipment whose characteristics theoretically optimized the QoS. Also, the access to data and information of configuration of the main router of the network was limited by the Office of Information Technologies and Communication of the university. Due to administrative reasons and to safeguard the confidentiality of information that circulates through the VLANs of management. For a more accurate study, these limitations can be remedied with greater investment and try with equipment of different models and features that of a better cost-benefit.

For future research it is advisable to analyze and better understand the phenomenon of refraction, reflection, and diffraction in the radio waves produced by wireless routers, it is also necessary to obtain the power losses caused by the type of material in the walls and even the 3D design of the infrastructure using more specialized software, it is also important to consider the environmental conditions that cause losses in signal power. The software used under Recommendation ITU-R P.1238-9 resulted in a minimum error rate of 8.7%, for better results it is recommended to work with the software of greater sensitivity and precision.

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Graduation Certificate Verification Model: A Preliminary Study

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***Abstract*—Graduation certificates issued by universities and other educational institutions are one of the most important documents for a graduate. It is a proof of graduate's qualifications and can be used to advance forward in one's career and life. However, due to advances in software, printing and photocopying technologies, forgery of those certificates is made easy and as good as the original, making them difficult to detect. Several universities and educational institutions as well as businesses started to dedicate resources for verifying certificates however that is usually a tedious and quite costly process and there isn't a clear model that can be adopted by those institutions that could minimize cost and speed up the process. There are many techniques proposed for paper based document verification and this paper analyzes and expatiate the issues on those techniques. Most of the verification techniques require change in the process of certificate generation either by changing template, changing paper, changing printers, adding hardware or even adding extra information. This change may mean that the university or verifier needs the proper knowledge to execute and run the proposed technique. This also means that older certificates may not work with the newly introduced techniques. To also add some proposed techniques require a change that is not always easy or cheap like in creating a third body to verify certificates.**

***Keywords*—Graduation certificate verification; graduation certificate authentication; graduation certificate forgery**

I. Introduction

Document verification is a vast field such that there is bank type of documents, governmental type of documents, transactions type of document, educational certificates type of document and many more other kinds. Each of the domain and types can be treated differently and the content vary tremendously. For example transactions can contain number in tabular form while educational certification may contain only textual information presented in paragraphs. Due to the vast differences in types of documents and how they are presented the research will focus on digital verification of paper-based graduation certificates. Verification is the process of determining or confirming that someone (or something) is original. Documents Verification on the other hands can be define in various ways such as the researchers [1] defines document verification as the process of proving the correctness or authenticity of a document by using a proven method or technique. While the researchers [2] defines it as the process of ensuring that documents received from holder are genuine and that the holder is the rightful owner. The problem is that the verification of certificates is costly and time consuming using the traditional methods in which the person to verify calls the issuing institute to make sure that said certificate is correct and that the information is real [2],[3],[4],[5]. For example, when a certificate holder applies for a position or a seat at some university the certificate holder either sends a copy by post or email or even faxes a copy to the place of interest. The place of interest accordingly verifies that the holder's certificate is real and not forged and that the information is real. And it is the dominant method. The traditional approach is time consuming and costly for both the place of interest as well as the issuer since resources would be allocated by both parties just to do one verification. It can grow exponentially costly if the process is repetitive. If the place of interest opted-for does not verify submitted certificates it can suffer great damages. Such that it will be more costly to recruit individuals especially in the long run because the company will have to suffer from the unqualified personnel and hence bad performance for the company which also means loss of money and reputation; this in turn will also mean higher employee turnover. Ultimately this will lead to loss of market value. That lead the researchers to investigate the techniques which can be used for document verification. The next sub-sections will dive in details of document verification such as its aim, its workflow and types of documents.

II. Document Verification

The main aim of document verification is the ability to trace the origins of a document to a specific person, the device that produced it or the place where it was produced [6]. Forgeries pose a huge threat to the integrity of documents, with significant dangers in terms of authentication and trust. It is therefore important to protect the integrity of a document in order to prevent problems arising from the modification of a document by intruders [6]. According to the research conducted by [4], all documents or credentials that are printed are potentially subject to counterfeiting and forgery. Forgery can cause a lot of damage when it comes to trust and authenticity [7].

There is a high market for forgery as well as opportunity with low cost, high quality results available [1]. Researchers have also found several significant problem areas when it comes to document verification. For instance, the technologies that are put forth to stop or prevent forgery do not seem to be moving as fast as the evolution of the forging techniques [8]. With respect to academic documents, further authentication problems include the variations from one school to the next, which causes consistency issues that can be taken advantage of, especially in international situations [9].

There are two basic document categories that are considered in document verification literature; digital based documents and the traditional paper or printed document. The research in this case deals with certificates. Almost all documents can be handled in a digital manner, except for the certificate. The reason for this exception is that all digital documents are easy to forge without leaving any clues [10]. Furthermore, the prevalence of forged certificates results from the increased global demand for higher education, which exceeds the university capacity of the world [9].

According to the research conducted by [10] there are two main types of forgery, type 1 and type 2. Type 1 forgery is when some part of the original document is changed in order to benefit someone who was not benefitted by the original document. In this case, the base substance, normally the paper or plastic card, remains legal and valid, but the information that is contained therein is forged. The second, type 2 forgery is when both the base substance and the information contained therein is fake. However, it is often very difficult to tell whether it is real or fake because the base substance and the style of the document normally look authentic [10]. The researchers of the research [10] outlined the characteristics of the classic unforgeable document. They also outlined three principles of the unforgeable document as follows;

1) The forged document normally has some difference from an authentic original document in some way

2) The detection of the forgery can happen without reference to the authentic original document

3) There is a concrete verification method that does not necessarily involve communication with an authentication bureau

III. Document Verification Workflow

There are three entities must be present to accomplish the process of document verification which are the issuer, the owner and the verifier. The issuer represents the entity that issues the document such as an educational institution or business organization or even a charity organization. The owner represents the person who owns the document. The verifier represents the employer/third parity that verifies the document. Based on that, the document verification workflow can be diagrammatically represented in Fig. 1

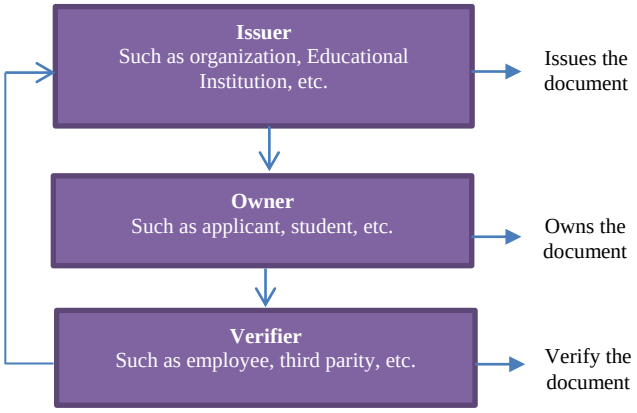

Fig. 1. Document Verification Workflow.

IV. Types of Documents

Documents can be categorized to two categories which are paper based documents and digital based document [10]. Paper based document contains characters, digits, tables, etc. Its digital version or digital document is a computer file. Digital document is designed to produce visual information on the computer monitor [10]. Forgery of documents has increased jeopardizing the integrity of both the document holder and the organization that issued the document [4-5]. The forgery of document is classified into two types which are 1) altering part of an authentic document that is original and 2) producing a new fake certificate with false information [10]. Forgery of document has become easier than the past mainly because of the technological advancements. For example scanning and printing hardware are much more advanced than they use to and are not as expensive add to that the editing software that are widely spread and constantly being updated and enhanced. Unfortunately as document forgery has become easier the increase of fake document has also increased. The latter is due to the lack in advancements in securing as well as verifying the paper-based documents [2],[6]. In other words documents securing and verification are not advancing as fast as the tools that enable forgery are. For that, the document verification became an important task; it is the process of ensuring that documents presented by prospective employees are genuine and that the holder is the rightful owner.

V. Paper based Document

This section will describe and detail on the first type of documents mentioned earlier and is the paper based documents. Its importance is described and also how they are verified.

A. Importance of Paper based Document Verification

The paper based documents are still widely used. There are many types of paper based document such as graduation certificates, birth certificates, etc. The information inside the paper based documents are subject to threats like forgery; despite measures taken to protect them attacks still happen. Author in [8] attributes that to the lack of verification. There are many cases where documents where forged throughout the globe. For example one that happened in New Delhi, where five people obtained loans and cheated the banks using fake documents [6]. Another example is one that happened in Bagdad, an investigation of 20,000 government employees by Iraqi's parliament showed that some employees have used forged educational certificates and fake diplomas to get their jobs. The issue extended in that those employees that used fake certificates became senior officials in the government [6]. Forgery of documents can happen in any discipline or line of work. In U.S. for example, The National Health Care Anti-Fraud Association projected that United States of America lost 3% to 10% of total healthcare cost to fraud [12]. Another example of forgery that happened in an area that involved the medical discipline is in Malaysia. The mainstream newspaper reported that a statement given by the Congress of Unions of Employees in the Public and Civil Services (CUEPACS) stated that more than 45,000 or 3% of 1.5 million government's staff in Malaysia forged medical certificate as a reason of absence from work to do part-time jobs. Another discipline that was impacted is Education. For example the prominent University

of Newcastle let out 50 students because they used forged certificates. The lecturers later on the course figured out that those students were unable to keep up with their studies and made them suspicious. That lead to a verification process, the university discovered that the English language certificate and degree certificate were forged.

With that has been mentioned document verification is important to overcome many issues that could even do with life and death. Imagine a doctor forging his way into a medical school. Or a politician forging his way to power. As a result, many could be harmed of such a behavior. Document verification of a paper based document has to be efficient to allow of seamless verification.

VI. The Graduation Certificate

A university is an example of an organization that creates so many documents for their students. It issues a certificate and academic transcript for each of its graduates. The certificate contains information that certifies a person has graduated from a certain specialization and obtained results as stipulated in the certificate. The certificate can then be used for job hunting or pursuing academics or any other purpose. The graduation certificate issued by the universities/institutions is one of the important documents for the graduate. It is a proof of graduate's qualification and can be used anywhere. Every year millions of students graduate from colleges and Universities, and their numbers are growing. Institutions issue certificates to those who have successfully completed the requirements of graduation. A graduation certificate is still in the form of a paper-based document because, as of yet, an electronic document cannot effectively replace a physical certificate [13]. With the rise of graduates and advancements in printing and photocopying technologies, came the rise of fake certificates as well threatening the integrity of both the certificate holder and the university that has issued the certificate [4-18]. This means that document validation and verification has become an important task The graduation certificate has to be verified to ensure that its content is true and also to ensure that the issued certificate comes from a real source [2]. Fake certificates can be created easily and the quality of a fake certificate can now be as good as the original. The certificates of many prominent universities have been forged and these forgeries are very difficult to detect. Educational establishments try to combat fraud and forgery in several ways [7]; however, most of the methods are time consuming because they are manual and involve human interaction. A lot of the time is spent in either reaching out to the university to verify a certificate or in awaiting a reply from the university that the certificate is valid and true. This process can be extremely laborious and expensive especially if a company needs to check the certificates of several hundreds of applicants. This adds to need of having a cost effective fast solution to verify certificates.

A. Importance of Graduate Certificate

Graduate certificates are of great importance to land a job or pursue further education they are the proof that the holder possesses the necessary knowledge to take a given position or pursue education. If these certificates are forged the whole foundation could collapse such that the employee would hold a position is not entitled to and could ruin or bring down the company. If it is in an educational institution it could mean many things of which a seat could be occupied by unworthy person instead of a worthy person. The graduate certificate as mentioned earlier can either be paper based or digital.

B. Paper-Based Certificate

Paper based certificates are still widely spread mostly because it is considered more secure than the digital certificate [6],[8]. Paper based certificate have stamps and signatures on them which can reflect originality [14]. Many entities require a stamp and a signature to accept a given document and graduation certificates are no different. However, the issue that arises is that the holder would be bound to providing the original copy every time the stamp and signatures are required. Another importance for paper based certificate is that they are easy to note from and on; Say the manuscript; modules can easily be highlighted and marked. Allowing multiple reviewers to go through it and do the same.

Paper based certificates despite being widely used they can be damaging. The most important disadvantages are:

- With paper based certificates is risk of loss and damage. Paper based certificates can easily be lost especially now as it is easy to relocate between different places and countries.
- Paper-based certificates is that they can be costly especially if changes are required on the document; for example a faulty name was printed, more papers would have to be used and that extra cost for the entity issuing the certificate; this indirectly also effects the environment.
- Paper based certificates can easily be damaged be it a wet hand or a fire in the building; Once the paper documents are damaged they are usually hard to recover. The holder either has to travel to source to generate the same or if the same is not regenerated it is a loss [15].
- Paper based certificates can eventually consume physical space.
- Paper based certificates can be slow to retrieve.

Despite these drawbacks with Paper based certificates entities still use it.

C. Digital based Certificate

The graduate digital certificate is the certificate that is issued in a digital form. It usually issued through a secure certification and verification method [16]. It is mostly adopted in order to solve the management problems of paper based certificate [15]. However one of the important reasons why digital certificates are widely adopted is that digital certificates provide a unique feature which is portability [17]; it is easy to transfer documents when they are digital.

Digital based certificates are considered environment friendly and can easily be organized without taking much space. The digital certificates in the simplest form is the easiest to forge without the need for special hardware [17]. Editing softwares are widely spread and changes to manuscripts and graduation certificates can easily be made. Digital certificates

are easily generated and can be amended with ease. Despite the advantages the digital based certificates they are not widely spread as the paper based certificates and are not the preferred method for many universities. Even if digital based certificates are issued paper based certificates are still required and needed.

VII. Related Work

There are several incidents where fake documents were discovered. As a result, many techniques arose like holograms, stamps and wet-signatures [2],[7]. However, these techniques can easily be replicated to create forged documents. Fortunately, there are continuous researches aiming to provide newer and better means to authenticate, validate, and verify the paper based documents. This made for several techniques to verify the paper based documents.

Signature extraction is a technique applied to verify bank cheques [18]. Signatures are of great importance in any paper based document. The availability of signature reflects the authenticity of document and level of authority that handled the document. For that in the conducted research [18], they focused on the signature verification only and they only targeted bank cheques. Their proposed system utilizes their signature database for verification. Given this research is focusing on graduate certificates this solution may not be the best solution to adopt for graduation certifications simply because 1) using the signature on its own would not ensure that the certificate is not forged and that the information is correct; the signature merely reflects that the document has been authorized by a specific person. This does not ensure in any way that the content is valid and is correct. Another issue with this approach is that 2) it still can be forged. Anyone can just copy the original signature and with the right tools a new certificate is created. Documents can be forged and the same signature used; the system will simply identify the signature and ensure that it exists in the database of signatures. The third issue with the proposed approach is that the technique was proposed with bank cheques in mind. Bank cheques have specific formats and templates than graduation certifications.

Print signature is another technique which is proposed to verify tickets [19]. Print signature has two procedures which are the 1) registration and 2) authentication. The registration procedure is given to the document to be protected; and the authentication procedure is to verify the authenticity and originality of the printed document. The verification process is made based on Optical character recognition (OCR) techniques. The OCR technique is made by fetching the features of document to be verified and then matched with saved features in database or somewhere else. The solution was made for tickets and tickets have different format and theme than graduation certification. The technique could be adopted to verify the graduation certification however the proposition as is would not work because 1) this may verify the content however it does not verify the source or where it was issued from. 2) saving the features to recognize later was made for tickets and not graduate certificates. 3) to save the features on a database may not be the safest approach. If the database is exposed the verification process will fail. The best approach is that if an algorithm verifies on the fly without the need to store the sensitive details needed to verify on the database.

The use of hash value for verification was proposed by the researchers [20]. The proposed method in the conducted research contains two stages which are document enrolment stage and authentication stage. They proposed to compute a hash value in the document enrolment stage and then store it in hash value database. The document is authenticated through computing the hash value again in the authentication stage and compared to the hash value in the database. If it matched, the document is authentic and if it not, the document is not authentic. The generation of hash value depends on the content in the certificate which will help in protecting the document from any changes. However, this approach does not consider securing the stored hashed value from leakage or being attacked.

Barcode is one of the most well-known approaches which can be used for document verification. Barcode technology is one of the most important parts of AIDC. The barcode can be analyzed to obtain the hided data. In term of encoding type, the barcode can be classified into two categories, namely, are 1D barcode and 2D barcode. The 1D barcode usually consists of varying of parallel lines different in both widths and space. Barcode offers several benefits such as High data capacity; error correction ability; and no additional storages [21]. 2D barcode can be used to hold information in both sides horizontally and vertically. Its content can be recovered reliably by scanning and decoding of the barcode. The main use of 2D barcode is to hold significant amount of data, typically of the order of 500 bytes per square inch. One of the main advantages of 2D barcode is that it can be printed on paper by normal printers and scanned by normal scanners [22].

2D barcode to verify the hardcopy of mark sheets [2]. The 2D barcode contains the encrypted data of the document. For document verification, they proposed an application which scans the 2D barcode and the document image to process it. The application reads the document image line by line utilizing OCR technique to recognize the text in the image of the document taken. Their proposed process to decrypt the information from the 2D barcode. The proposed method has advantage over the techniques which was proposed by [9],[16], as they proposed to encrypt the information however; the drawbacks of the proposed method is somewhat similar to the drawbacks in using the QR codes and are: 1) modifications has to be in the printed certificate; 2) availability of public key; 3) older documents without the 2d barcode cannot be verified.

The researchers [7] suggested somewhat similar verification approach to the researchers [2]. They proposed to embed the hashed unique key generated from the timestamp, track number and the content of document into 2D barcode. For document verification, they proposed to scan the document using OCR techniques. The text of the document along with the timestamp and the tracking number will be extracted from the 2d barcode. However the extracted data is hashed using hashing algorithm. The generated hash value is matching with the hash value stored in 2D barcode. If the hash values are same, the document is original else the document is fake. The proposed method is adopted within same organization.

Similar to the verification approach which was proposed by [7], the researchers [6] also proposed to use 2D barcode.

however their intention was to verify documents sent from point A to point B with a known sender and receiver. The verification method is proposed based on a scenario where user A wants to send document to user B and user B wants to verify the sent document sent by A. Hence, they proposed that the important parts of the document such as time stamp, issuing number, sender signature and hashing value of the content of the document be embedded in the 2D barcode. For document verification, the receiver decrypts the content through scanning the 2D barcode. This approach added extra details to the embedded data in the bar code however these details may not be needed in graduation certificate and it is suffer similar drawbacks to [2] mentioned earlier.

The QR code is one of 2D barcode types; it was first designed in Japan, and then later became more popular. QR code offers several benefits such as fast reading; high storage capacity, etc. It is was developed by Denso Corporation in 1994. QR code nowadays are adopted for different uses as well as different applications. It has been used in transport ticketing, commercial tracking, identity verification and website Uniform Resource Locator (URL) [14-18]. QR code comes in various sizes and versions. The smallest size is of 21x21 modules; it was the first version. The latest version is 40 which come in size of 177x177 (inch). QR codes have four levels of error correction which are, namely, L, M, Q, H; these levels are different in the rate of error correction like 7% is in the level L; 15% in M; 25% in Q and 30% in H [6-20]. However; the QR code capacity is based on its version and its level of error correction. QR code can hold up to 7089 characters of numerical data; 4296 characters of alphanumeric. QR code has several benefits like high capability of error correction; can be scanned from any direction; support different encoding types and versions, etc.

QR codes as a mean of paper based document authentication [23]. Their proposed method can only be applied between known sender and receiver. for each party there are set of procedures. They proposed to generate hash value from the message then the hash value is encrypted with the private key of the sender. This forms the digital signature. The message and the digital signature are then combined and compressed and embedded in the QR code. The QR code is printed on the paper and then sent to the receiver.

The QR code in the document is scanned first, the data of QR code is decrypted in order to obtain the embedded message and digital signature. The digital signature is decrypted using the sender's public key. Their proposed technique of document verification is similar to the proposed approach by [24],[25].

In the research conducted by [9] and [14], they proposed to keep the information in a database instead of a QR code. A QR code scanner must be used to scan the QR code.

QR code is another technique which proposed to be utilized for document verification. For example, in the research conducted by [3],[26] the researcher proposed to use of QR codes on degree certifications, they proposed a scheme to generate the QR code. The scheme is a set of procedures. The first being composing the student details; followed by generation of a hash value from the composed details; after that the digital signature is composed using the university's private key; the content along with digital signature are combined and embedded into the QR code and QR code is printed on the bottom of the certificate.

For degree certificate authentication, they proposed a scheme similar to the approach which proposed by [23] and is scanning the QR code from the certificate; decrypting the details off the QR code; generating new hash value from the content of certificate that at hand and then matching process is done to compare the hash value. If the hash values are same, it means the certificate is authentic. if not, it means the content is altered and the certificate is fake. It is clear from the creation and verification process of the proposed method is that it is similar to the method proposed by the researchers of [23] and [27]. However, their solution unfortunately is under a license, which means for any entity to adopt the said solution the license must be purchased.

In the research conducted by [28], they suggested leveling up document verification by adopting a two level QR code. The two level QR code means that the QR code has two levels of storage; the information is stored in the first level and the second level is created by replacing the black modules with specific textured patterns. The texture patterns are related to print and scan process and they are sensitive. For document verification, the 2LQR is scanned. This proposition is mostly useful to verify the documents within same organization. Also document content were not considered.

Watermarked QR code is also an approach which is proposed for document verification [1]. Watermarked QR code contains the QR barcode, validation link to a website where it will show result and logo image. The logo image is for identifying the owner who generated the QR code. In the research conducted by [1], they proposed a process to embed the validation link into the QR code and then generate the QR code. The watermark logo is embedded into QR code image. For document verification, they proposed scanning the watermarked QR code using QR reader. The proposed process is very simple; however they only focused on validating the institution that issued the document and not the content or whether the content is correct.

RFID is another technique used for document verification. RFID stands for Radio Frequency Identification; it uses the radio frequency waves to transfer data. The data is transferred between two entities which are the reader and moveable item. The moveable item is tagged to categorize, identify and track it [25],[29]. In the research conducted by [30], they developed smart degree system based on RFID.Their system utilized the fingerprint of graduates for the purpose of certificate verification. They proposed that the university issues the certificates with RFID tags; this tag contains the important information related to the graduate like name, graduation date, the program, the degree and biometrics (fingerprint) of the graduate. For certificate verification, an interrogator must be used to read the embedded data in the tag and also the verifier have to log into a website which is usually indicated in the back of the certificate, and download the required software to enable interpreting the tag. The issue with the proposed solution is that the process of authentication is time consuming, especially that the external entities that might verify the

certificate will have to download a software in order to read the encrypted data along with the need to have an RFID reader to read the tag and download its data. Another major problem associated with approach is that the certificates mailed or copies cannot be verified since they will lack the RFID in them. The original certificate has to be present and this is not a feasible solution making RFIDs useless for graduate certificates.

The other dominant approach utilized in document verification is digital watermarking [31],[32]. It is a technique that can be utilized for protecting the copyrights or ownership; it also can be used to prevent forgery in printed documents. It is a method that can be used to embed some information in the cover image. This information can later be extracted and processed. The way watermarking works in the simplest form is through embedding the main information of document as a watermark in the same document. For document verification, the hidden information can be extracted using certain algorithms [33]. Usually it is very hard to notice the embedded watermark by the human naked eyes, hence if tools like OCR is used to read the contents the watermark would be lost [8]. The drawbacks of using watermarking is that it can easily be lost when transforming paper-baser to digital and vice-versa. Also to add it requires change in the type of paper used for certificates as well as the process of generating the certificate. As for digital watermarking generally graduate certificate are not all digital and still are being paper-based and so is most of real-life documents [34].

Based on what has been presented in the previous sections, there are many techniques proposed for paper based document verification. Most of these techniques require change in the process of certificate generation either by changing template, changing paper, changing printers, adding hardware or even adding extra information. This change may mean that the university or verifier need the proper knowledge to execute and run the proposed technique. This also mean that older certificates may not work with the new introduced techniques. To also add some proposed techniques require a change that is not always easy or cheap like in creating a third body to verify certificates.

As reflected some techniques are mostly suitable for specific domain and document like signature extraction for bank cheques. Others were proposed based on specific environments and conditions like environments that assumes both send and receive are known to each other [2],[35].

VIII. Discussion

With today's availability of low-cost scanning devices, high-quality printers and better color copy machines, the production and circulation of fake certificates became cheap and easy because a paper document can easily be forged [3],[11]; however, the forgery of important document like graduation certificate became a real issue. The 21th century has experience a lot of fraudulent activities and misconduct most especially in the practices of certificate forgery. The resultant effect of these habits in most cases normally reduces the integrity of institution concern [28]. Hence, anti-counterfeit method has becoming a worldwide research focus.

It is clearly shown in the previous sections that there are some proposed techniques that were made with graduation certificates in mind and there are other techniques made for other purposes that could be adopted to verify the graduate certificates such as QR code, 2D barcode, watermarked QR code and RFIDs. An RFID tag solution is very complex, costly process and the lifetimes of such devices are very limited [16]. A very popular approach, often used in practice, is watermark. It usually provide a good protection against forgery, but they are costly and often not included in real-life documents [34]. compared to computer chips and RFID tags, data hiding technologies like Quick Response (QR) code are much cheaper and do not require specialized hardware for retrieving data. QR codes are inexpensive, and they are passive read-only elements whose content cannot be altered. Decoding of the QR code can be done by many low-cost devices, including smart phones. As QR Code has high capacity, all the standardized features extracted from the fingerprints could be encoded in it. It can be read from any direction and standard encryption techniques can be applied to the QR code to make it even more secure [36]. With each of these techniques there are limitations as reflected earlier. Despite the scare resources in literature, the available literature that focuses on graduate certificate verification is very limited and also there is no clear model to graduate certificates verification that could be adopted by universities. Universities do not have a model to work with they simply execute different techniques which are not necessarily suitable and cost effective. The verification process can consume a lot of resources (time and money) for both entities the issuer and verifier. For example, the verifier would call the university and the university would interns consult its records and reply to the verifier. This process is tedious and resources hungry. That is why there ought to be a model that balances the cost effectiveness and efficiency. The verification process of paper based documents varies in three dimensions the first being the tools used. The second the scope and the third being the procedure of verification.

1) Procedure: The researchers of [4],[29] suggest scanning the document then verify.

2) Tools: In the research conducted by [20], they suggest OCR techniques for automatic verification. While in the research conducted by [6], [7], they suggest utilizes Smart phones with cameras. And there are other approaches that involves adoption of extra hardware such as RFIDs, such an approach requires an interrogator to read the embedded data in the tag and also the verifier has to log into a website which is indicated in the back of the certificate, and download the required softwares add to that the original certificate with the RFID has to be present. From the previously stated, it can be concluded that the verification process of paper based document requires either extra software, changes to the current certificates and also can require extra hardware. Paper based document verification still need to be further enhanced to increase of the verification speed and make it effective and reliable.

3) Scope: The other characteristic if verification is the scope. The verification process is proposed between sender and receiver [6],[7]. While the proposed process of document

verification is only carried out within their own organization [21],[37]. The verification process is only useful if the verifier is known for the issuer. However; the drawback with this process is that the third parity would have to manually communicate with the organization issuing to verify the document and this consumes a lot of time and hence becomes costly (cost of calling, assigning personal to call and of course allocating necessary resources to respond to the said request).

IX. Conclusion

With the rise of human population came the rise of educational institution to accommodate the population. However, this has introduced some problems to many organizations and to the educational institutions themselves. One of the most important problems is Verification. There are ways institutes try to combat frauds and forgeries however mostly are time consuming because they are manual and it involves human interaction. The time spent is either reaching out to the university to verify a given certificate or awaiting a reply from the university that issue the certificate. This latter can be extremely exhausting and expensive especially if a company does it for several hundreds of applicants. As presented in this study there isn't a clear model for verification. Even though there are researches taking place to enhance verification of documents; the graduation documents verification researches are very scarce. Little research is dedicated to graduation documents verification. Aside from that the techniques presented each has its flaws for seamless unified certification verification. In future work, authors will design and develop a clear model for graduation certificates verification.

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New Approach based on Machine Learning for Short-Term Mortality Prediction in Neonatal Intensive Care Unit

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***Abstract*—Mortality remains one of the most important outcomes to predict in Intensive Care Units (ICUs). In fact, the sooner mortality is predicted, the better critical decisions are made by doctors based on patient's illness severity. In this paper, a new approach based on Machine Learning (ML) techniques for short-term mortality prediction in Neonatal Intensive Care Unit (NICU) is proposed. This approach relies on many steps. At first, relevant features are selected from available data upon neonates' admission and from the time-series variables collected within the two first hours of stay in the NICU from the Medical Information Mart for Intensive Care III (MIMIC-III). After that, to predict mortality, many classifiers were tested which are Linear Discriminant Analysis (LDA), K-Nearest Neighbors (KNN), Classification and Regression Trees (CART), Logistic Regression (LR), Support Vector Machine (SVM), Naïve Bayes (NB) and Random Forest (RF). The experimental results showed that LDA was the best performing classifier with an accuracy equal to 0.947 and AUROC equal to 0.97 with 31 features. The third step of this approach is mortality time prediction using the Galaxy-Random Forest method achieving an f-score equal to 0.871. The proposed approach compared favorably in terms of time, accuracy and AUROC with existing scoring systems and ML techniques. It is the first work predicting neonates mortality based on ML techniques and time-series data after only two hours of admission to the NICU.**

Keywords*—Mortality prediction; neonates; Intensive Care Units; machine learning

I. Introduction

Intensive Care Units (ICUs) are a hospital department [1] where doctors make the most important, complex and uncertain decisions. It's also the place where we find patients, with critical health conditions following accidents, prematurity, surgical complications, severe breathing problems, infections and serious injuries [2]. These patients need constant and close monitoring with sophisticated technology for body function maintain [3]. This sophisticated technology is expensive and not very abundant in ICUs which makes its good management a way for great gain in health care costs by reducing them remarkably. Then, predicting outcomes like mortality in similar contexts, helps doctors to do efficient resources allocation [4], to easily make critical decisions, to compare medication, to define care levels, to reduce health care costs and to discuss with patients' families about expected outcomes. The importance of mortality prediction resulted in many studies on relevant topics ranging from severity scoring systems and statistical methods to Machine Learning Techniques.

For years, scoring systems, also called severity scoring models or risk prediction models, were used by doctors to assess illness severity [5]. This estimate is based on fixed variables and coefficients that require the collection of a large amount of clinical information. However, for primary hospitals, this is not practical and even not very feasible in some cases. The second limitation of scoring systems appears when applied on a population different from that one on which they were developed. Therefore, because of these disadvantages and technological developments, statistical analysis and machine learning techniques have taken the place of classical methods. In fact, models developed locally are more flexible, quickly updated and improved which makes them more adapted for prediction than the standard severity scoring systems [6]. On another side, in terms of early mortality prediction, neonates scoring systems predict mortality from 12 and 24 hours since admission to the ICU except for Clinical Risk Index for Babies II (CRIBII) [7] which predicts mortality after one hour of admission. But, in addition to being purely statistically derived, the value of one of CRIB II variables used for the calculation, which is the maximum base deficit, covers the first 12 hours of admission. Likewise, many works based on machine learning techniques predicted neonates mortality after the first 12, 18, 24, 36, 48 and 72 hours of admission[8]. Even the model proposed by Veith et al. [9], predicting mortality at admission, is not specific to neonates and does not use clinical data.

So, because of mentioned limitations related to scoring systems and because the earliest work in mortality prediction for neonates using ML techniques and clinical data predicts mortality after 12 hours, the goal of the present paper is to provide a new approach for short-term mortality and death hour predictions based on time-series variables and data collected upon neonate's arrival to the NICU and 2 hours after admission. The proposed approach employs an ensemble of classifiers such as Support Vector Machine, Logistic Regression, Linear Discriminant Analysis, K-Nearest Neighbors, Classification and Regression Trees, Naïve Bayes and Random Forest to predict in-hospital mortality. Galaxy-Random Forest is also used, for the first time in such context, to predict the time interval in which mortality occurs. The big health care MIMIC-III [10] database was used to design models for mortality estimation.

The rest of this paper is structured into five sections: the literature review is presented in Section 2. Section 3 presents the methodology in which work steps are described. In Section 4, results found during the performance evaluation of the proposed approach are exposed. Finally, in Sections 5 and 6, respectively, the results are discussed and the paper is concluded.

II. Related Works

In this section, works already done in neonates mortality prediction are reviewed, starting with scoring systems and going towards solutions based on machine learning techniques.

A. Scoring Systems

Neonates mortality may have several causes and the major one is prematurity [3]. Indeed, in case of prematurity, mortality risk increases especially when accompanied by a gestational age < 28 weeks and a birth weight < 1000 grams, which is generally the case [11]-[12]. Thus, birth weight was one of the most used indicators for mortality prediction which hampered developing scoring systems specific to neonates compared to those of older people. However, admitting the existence of other factors besides the birth weight which can have an effect on mortality and morbidity, a variety of neonate scoring systems, also known as risk adjustment scores, were developed in order to predict neonates mortality. Yet, they have not shown the same relevance. In addition to that, they work on data collected over different time intervals ranging from one hour after admission to the ICU to 24 hours and more.

The Clinical Risk Index for Babies (CRIB) [13] predicts mortality of infants with gestation less than 32 weeks at birth based on 6 variables collected in the first 12 hours after admission. Birth weight, gestation, congenital malformation, maximum base deficit in 12 hours, minimum and maximum appropriate FIO_2 in first 12 hours are these 6 most predictive factors according to logistic regression. Compared to other scoring systems, CRIB is less susceptible to treatment effects, the calculation takes five minutes per infant and the data required is easily collected. CRIB II [14] is an update of CRIB mainly affecting prediction time which went from 12 to the 1st hour of life. Birth defects and variables influenced by infant's care giving were excluded.

The Score for Neonatal Acute Physiology (SNAP) [15] predicts neonates' in-hospital mortality based on the least favorable first 24 hours physiologic measurements after admission counting 28 items. A score going from 0 to 5 is assigned to each item according to expert opinion. SNAP-Prenatal Extension (SNAP-PE) [15] uses SNAP scores in addition of birth weight, an APGAR score less than 7 at 5 minutes and small for gestational age to predict neonate's in-hospital mortality. SNAP II [16] and SNAP-PE II [5] are updates to previous scores which predict well mortality but raise the problem of data collection difficulty. This update saved 4 minutes in the scoring time. Such result was achieved following the data collection time interval change to 12 instead of 24 hours after admission. It was also reached after keeping only 6 variables which are strongly associated to death.

Other scores were developed but did not have the same success as those mentioned previously. The National Therapeutic Intervention Scoring System (NTISS) [7] is based on the treatment received by the patient, something that depends on the practices and unitary policy which makes this score unusual. Moreover, other scoring systems have suffered the same fate as The Berlin Score [7] because of its inclusion of subjective factors or the National Institute of Child Health and Human Development (NICHHD) and the Neonatal Mortality Prognosis Index (NMPI) that have not been widely used since development [7].

Although scoring systems have shown better mortality prediction compared to birth weight, they suffer from many issues. They remain not completely accurate due to the complexity of the neonatal clinical process and updates to these systems are a proof that they need adaptation to keep their effectiveness. They are not very flexible since they are based on specific data to be calculated. Also, individual outcomes prediction is not very feasible because of the variation in care approaches from one unit to another and even within the same unit. Moreover, in case of short-term mortality prediction in NICU, models meeting this need are not really suitable for this purpose. As a result, the need for other solutions to predict mortality has emerged.

B. Machine Learning Techniques

Machine learning techniques are more efficient than the standard severity scoring systems in the medical environment thanks to their ability to be improved and updated quickly. They are also more efficient than scoring systems when it's about a patient-specific prediction [6]. Indeed, the locally developed models have great flexibility and freedom to design customized models based on available data.

A Gaussian process classification was used by Rinta-Koski et al. [17] to predict preterm infant in-hospital mortality. They worked with 598 infants having weight under 1500 g which means very low birth weight. Data was collected from the Helsinki University Hospital database. SNAP-II and SNAPPE-II were calculated at arrival to the NICU. They also collected time series data for the first 72 hours of care to predict their outcomes. Evaluation also covered time periods ranging from 12 to 48 hours, passing by 18, 24 and 36 hours. With an AUC equal to 0.946, their proposed model outperformed clinical scores SNAP-II and SNAPPE-II.

To compare hospitals performance, Liu et al. [18] proposed an approach for mortality rate risk adjustment. It's based on Random Forest and Bart (Accuracies: Logistic Regression =0.93, Classification Random Forest =0.94, Regression Random Forest= 0.94, BART =0.95). This ensemble of tree methods performed better than logistic regression prediction accuracy for early born babies risk evaluation.

Artificial Neural Networks (ANNs) were used by Frize et al. [19] to build an automated tool predicting neonate's mortality 48 hours after admission (Sensitivity = 81%, Specificity = 98%). And by Saadah et al. [20] to predict mortality risk in case of nosocomial outbreaks of RSV(Sensitivity = 82%, Specificity = 100%). Cerqueira et al.

[21] also used ANN and Support Vector Machine (SVM) to design NICeSim which is an open-source simulator based on machine learning techniques to predict death probability of newborns(accuracy = 86.7%, AUC = 0.84).

C5.0 decision tree software was used by Gilchrist et al. [22] in order to develop a real-time mortality prediction model for 12, 24 and 48 hours. To validate the model, a 5-by-2 cross validation technique was used. And the F1-score was used to measure the performance of the model(Sensitivity = 63%, Specificity = 94%). According to authors, best predictors were serum pH, mean blood pressure, immature/total neutrophil ratio, respiratory rate, serum sodium, heart rate, serum glucose and pO2 blood oxygen level.

In their study, Townsend and Freize [23], worked on three outcomes which are Mortality, Length of Stay (LOS) and Ventilation Duration (DOV) 12 hours after admission. Models with risk estimation ranges were created using conjunction between the maximum likelihood (ML) approximation and a gradient descent artificial neural network (ANN). K-Nearest Neighbor (KNN) was used to solve the problem of missing values. The evaluation of the model's performance gave a sensitivity = 63% and a specificity = 99%.

A collaborative parent decision support system PADS, was proposed by Frize et al. [24] aiming to implicate parents in every step of decision-making with physicians in the NICU. Outcomes in this system, which are mortality, LOS (Length Of Stay) and Ventilation duration are estimated by Artificial Neural Network (ANN) (2n+1 hidden layers and n is the input number). After 24 hours of admission, estimations are delivered by the system. A kind of extension, named Physician-PArent Decision-Support PPADS, was proposed in 2013 [25]. It works with real-time data to predict mortality. The 5-by-2 cross validation was used to validate the model which was built based on "Multilayer Perceptron (MLP) feed-forward network with back-propagation" [25]. K-nearest neighbors was also used to deal with missing values.

In their work [9], not limited to neonates, Veith and Steele predicted patients mortality upon admission to the ICU based on machine learning techniques. They took patients data from the MIMIC-III database. Admission type, religion, ethnicity, marital status, the patient's insurance provider, language and previous location were attributes used in this work for the predictive model building. Their common point is the ease of their collection on admission. The best five performing algorithms were Logistic, Simple Logistic, LazyKStar, Bayes Net and Naïve Bayes. With 10-fold cross validation, they reached an AUC going from 0.721 to 0.689. With the training set they reached an AUC between 0.751 and 0.706.

The difference in the results, which is sometimes not too broad, reveals that there is no best machine learning technique over all situations and the performance of the model depends on the nature of the data and related problems as well as the context in which the prediction is conducted. However, some algorithms seem to perform better than others in certain aspects.

III. Materials and Methods

In this section, tools and methods used by the proposed approach for short-term mortality prediction in NICU are presented. Given the nature of the data monitored and collected, understanding data and dealing with probable problems related to it are the first challenges presented in this section. After that, features selection and the prediction model are presented.

A. DataBase

The data source in this study is the Medical Information Mart for Intensive Care III (MIMIC-III) [10]. It's a relational critical care database developed by the MIT Lab for Computational Physiology. MIMIC-III is more and more widely used thanks to its free accessibility. In this work, 1.4 is the used version (September 2016). MIMIC-III is composed by deidentified data coming from more than 40.000 critical care patients who have stayed in Beth Israel Deaconess Medical Center in Boston, Massachusetts. Many categories of data appear in the used database: demographics, laboratory measurements, vital signs, diagnosis and procedures codes, care givers observations and notes, fluid balance, medications and imaging reports. Data stored in MIMIC-III are related to 7.870 neonates, which means patients having an age under 28 days, and 38.597 distinct adults aged 16 years and over. The database has 26 tables and 324 attributes. Two million rows is the number of unstructured textual data existing in MIMIC-III and representing analyses and notes of various healthcare providers. In addition, we find 380 laboratory measurements and an average of 4.579 charted observations.

B. Data Preprocessing

After data collection, preprocessing is an important step in order to have data that strives for perfection and completeness which make it reliable for prediction tasks [26]. In order to reach such data, dealing with issues like missing values, duplication and normalization is a crucial task and it's the purpose of this section.

a) Data description and analysis: The path to the final dataset used in this study required a great preparation. It was long, packed with work and panoply of choices. Since neonates mortality prediction is the target in this work, only newborns with an age under 28 days were selected from MIMIC-III. 7.867 neonates was the size of the cohort comprising only 66 cases of death. Each patient from the selected cohort may have more than one admission and each admission may require several ICU stays, then we limited ourselves to patients' first stay in the ICU.

The final selection criterion was a kind of investigation about descriptors having impact on mortality based on previous studies and doctors' opinion. In fact, and as we mentioned above, prematurity is the major cause of neonatal mortality especially with a Gestational Age <28 weeks and a Birth Weight <1000 grams or less [11]-[12]. The APGAR score [27], which is a simple birth observation to evaluate newborn vitality, is also a good mortality predictor especially before 32 weeks of gestational age [28]. This score, can be estimated after 1, 5 and 10 minutes of birth. Only patients with APGAR scores under 10 minutes, which means scores for 1

and 5 minutes were kept, because the information was not available to all patients beyond this value at the time of this study. The final dataset consists of 800 patients counting 60 cases of in-hospital death and 740 survivals.

For mortality prediction, this work uses data collected at admission and during a time interval of 2 hours after admission to the ICU. Every patient record was composed by 7 general descriptors and a list of 164 time series variables. Static descriptors were collected automatically or manually from ADMISSIONS, ICUSTAYS, PATIENTS and NOTEEVENTS tables. Time series variables were collected from the CHARTEVENTS table, once, more than once or not at all. "ID" (a single integer identifying each admission to the ICU), "Gender", "Age" (days), "GA" (Gestational Age in weeks), "BW" (Birth Weight kg), "APGAR1" score for the first minute after birth and "APGAR5" score for the 5th minute since birth are the 7 descriptors. A timestamp indicating the time in hours and minutes is associated with each observation since admission to the ICU. From the list of time series variables, 58 appearing in 10% or more of the patient's records were kept. Table I shows the list of time series variables collected for this work, after deleting duplicated values, organized based on their coverage and appearing in 10% or more of the patient's records.

Finally, the 7 static descriptors ID, Age, Gender, BW, GA, APGAR1 and APGAR5 were kept as features. Similarly, attributes like Length, Present Weight, Head Circ, Day of Life were considered as features. On the other hand, we retained the average, the maximum and the minimum values for every time stamped variable in the time-series variables' final list.

a) Missing values: In a hospital environment and specifically in ICUs, a large amount of variables are measured. However, these measures are not always conducted and available at the same time for any patient and this is the reason for the frequent problem of missing data especially in early hours of admission. Unfair prediction or biased results can occur due to this issue. Thus, it's of interest to solve this problem from the preprocessing phase.

In the literature, three types of missing values exist: (1) Missing At Random (MAR), (2) Missing Completely At Random (MCAR) and (3) Not Missing At Random (NMAR) [29]-[30]. To address this problem, a multitude of approaches, which can be grouped into missing value imputation and case deletion, have emerged. Ignoring records containing missing values seems to be the most traditional approach and this is what is proposed by case deletion through its two deletion techniques working on MCAR only: Casewise and Listwise [29]. On the other hand, under the umbrella of missing value imputation, there are plenty of methods such as K-nearest Neighbor Imputation (KNNI), Concept Most Common Method, K-means Imputation, Regression Imputation, Expectation Maximization Imputation (EMI) and Multiple Imputation [29]. In the same context, Che et al. [31] used Recurrent Neural Networks (RNN) in their proposed solution to solve the problem of missing values in time series data. But, among all these techniques, using the mean or the average to replace missing values remains the Most Common Method in the case of Value Imputation.

TABLE. I. VARIABLES COLLECTED IN THE 2 FIRST HOURS OF ADMISSION TO ICU HAVING COVERAGE >= 10%

Variables	Coverage (%)
Heart Rate	98.5
SaO2	96.54
Resp Rate	94.81
HR Alarm [High]	88.81
HR Alarm [Low]	88.81
SaO2 Alarm [High]	87.43
SaO2 Alarm [Low]	87.43
BP Cuff [Diastolic]	83.85
BP Cuff [Mean]	83.85
BP Cuff [Systolic]	83.85
Temp (Skin temperature)	82.35
TIW(Temp/Iso/Warmer)	80.96
Glucometer (Glucose meter)	73.01
Temp Axillary	69.32
PH	57.09
FIO2 (Fractional Inspired Oxygen)	55.59
WBC (White Blood cell Count)	51.21
RBC(Red Blood cell Count)	50.4
BASOs	49.37
Eosinophils	49.37
LYMPHS	49.37
MONOs	49.37
NEUTS	49.37
Platelet	49.1
BANDS	48.9
Hematocrit	48.86
HGB	47.4
Flowrate	46.6
Humidity Temp [Meas]	44.75
PEEP	44.75
FIO2 [Meas]	44.41
Mean PAW	44.18
Polys	43.83
Head Circ	42.91
PEEP Alarm	42.45
High Pressure Relief	41.06
Mean PAW [Meas]	40.95
FIO2 Alarm [Low]	40.14
Total Fluids	37.37
Length	33.79
Temp Rectal	33.56
ETT Size (endotracheal tube size)	33.1
Present Weight	32.41
ETT Taped	31.26
PIP	25.84
Breath Rate	25.72
pCO2	25.61
Base Excess	25.49
pO2	25.49
Inspiratory Time	25.26
FIO2 Alarm [High]	25.14
PIP Alarm	23.53
TCO2	16.84
Day of Life	15.69
Sensitivity	13.49
Survanta	12.69
pH (Art)	12.34
Vt(Ventilator)	10.96

For the used dataset in this work, proceeding by two ways to solve the problem of missing data was the choice. Defining the rate of missing data for every variable and removing the ones having a rate over 50% was the first step. It allowed us to keep only 24 variables including the 7 initial descriptors. Then, for each remaining variable, the maximum, the minimum, the mean and the standard deviation were calculated and missing data were replaced by the mean value.

b) Class imbalance: Class imbalance is another quite common challenge in work with machine learning techniques. Indeed, in the medical field and when it comes to mortality prediction, we usually find ourselves in the case where only few instances belongs to the most significant class in learning task and this is what is named imbalanced classes. To solve this problem, several methods exist and they can be divided into three approaches [32]:

- Data level approach
- Algorithm level approach and
- Cost-sensitive approach.

Methods of the first approach, which is the followed one in this study, are under sampling, oversampling and hybrid. In this present work, given the size of dataset especially the number of cases of mortality and since some variables were eliminated in previous stages, oversampling was the solution. This technique increases the minority class records which are the class of dead patients.

C. Features Selection

After dealing with missing data and class imbalance, keeping only relevant attributes is a building stone in design of predictive models. Features selection aims to produce unaltered subset of attributes coming from the original variables for efficient prediction. The most important objectives of features selection are:

- Avoiding model overfitting
- Improving model performance (prediction performance and cluster detection).
- Reducing computation time
- Providing more cost-effective models
- Better generalizations models

According to [33]-[34], feature selection methods can be divided into three categories: filter methods, wrapper methods and embedded methods.

The first category, which is filter methods, includes CiS, Fish, Ttest, Info and Gini methods [34]. Variable selection is made regardless of the learning algorithms. Computation time effectiveness and robustness against overfitting are filter methods advantages [35]. On the other hand, selecting redundant variables is the disadvantages of these methods which make them more used in data preprocessing.

Under the umbrella of wrapper methods [34], which are the second category, we found search strategies like best-first search, genetic algorithms, hill-climbing search, sequential search and branch-and-bound search. They are proposed to reach optimal local learning performance. But, in practice, wrapper methods are rarely used despite allowing for the detection of possible interactions between variables thanks to variables subsets evaluation. Reasons of their rare use are computation time and overfitting [34]-[36]. In fact, with large variables number, computation time becomes important. The second disadvantage, increasing overfitting, takes place when we have insufficient observations.

The last category, which is embedded methods [35], is a kind of benefits combination of the previous techniques. In fact, there is no iterative feature evaluation although the inclusion of learning algorithm interactions. Regularization models are famous in embedded methods thanks to fitting errors minimization. They also force feature coefficients reduction to fit with learning models.

In this work, we tested two solutions for features selection in order to reach best features to use in classification to get a better performance. The first one is RFECV (Recursive Feature Elimination with Cross Validation). It's an iterative procedure and an instance of backward feature elimination aiming to train the classifier, compute the features' ranking criterion [37] and remove the ones having the smallest ranking criterion .The second one is tree based feature selection. This solution uses the feature importance method. Every feature has a feature importance attribute and the higher is the attribute the most important is the feature. Finally, to train the model, Random Forest (RF) was used as a classifier and its accuracy was used to compare the feature selection techniques.

D. Prediction Model

For the neonates' short-term mortality prediction after admission to the NICU, the proposed approach consists of three parts. Selecting the most relevant features is the first step in the mortality prediction model building. After that, classifying patients into mortals and survivals based on machine learning algorithms to select the best performing classifier is the second part. Tested algorithms were Logistic Regression (LR), Linear Discriminant Analysis (LDA), K-Nearest Neighbors (KNN), Classification and Regression Trees (CART), Naïve Bayes (NB), Support Vector Machine (SVM) and Random Forest (RF) [38]-[39].The third part is the build of the multi-label classification model to predict the hour of mortality of patients previously classified as mortals using Galaxy-Random Forest classification [40]. The global proposed approach is schematized in Fig. 1.

Galaxy-X Is a novel approach. Its purpose is multi-class classification. It's suitable for open-set recognition problems. Indeed, existing methods predicting outcomes in a closed-set of labels classify unknown instances based on known training classes. In such a case, misclassification of instances from unseen classes can occur. It's what is called open-set classification. In [40] this problem is treated by distinguishing instances that belongs to unknown classes from those similar to classes already seen. This distinction is possible thanks to the creation of a hyper-sphere having minimum bounding for each class of the training set. All instances of known classes will be included into this hyper-sphere [40]. Based on this

method, a given test instance will be classified in a space composed by known training classes and the unknown class. So, if the test instance belongs to unseen classes, it will take place in the unknown class.

To evaluate classifiers performance, Cross-Validation, Accuracy and Receiver Operating Characteristics (ROC) were the used metrics [41] in addition of Leave-P-Class-Out-CrossValidation [40] regarding the specificity of open-set classification.

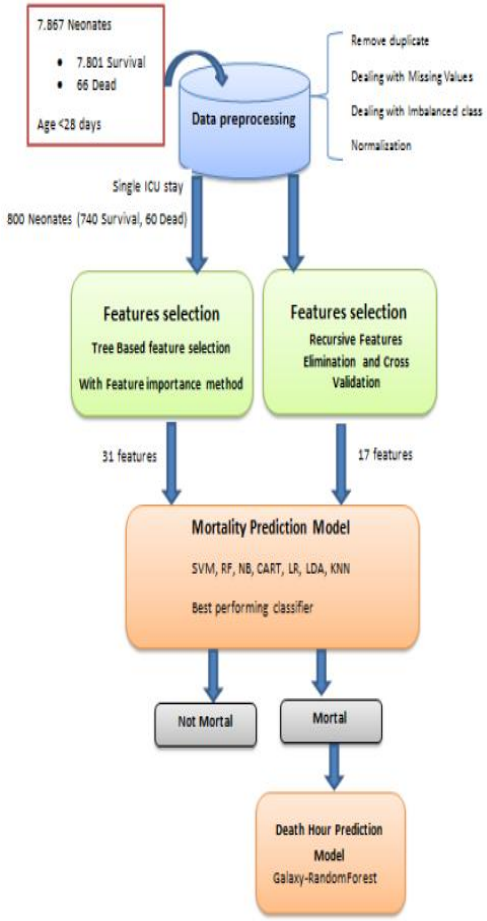

Fig. 1. Proposed Approach for Short-Term Mortality Prediction in NICU.

IV. Results

Fig. 2 shows the final list of 24 variables composed by 17 time series variables with missing values rates under 50% and 7 general descriptors. The number of attributes used in this work as a base for features selection goes from 24 to 58 because the 17 most frequent time series variables were presented each by minimum, maximum and average.

Based on the final list of 58 attribute and Random Forest classifier accuracy = 0.97 used in model training in order to compare features selection techniques, the first method of features selection, which is RFECV, allowed us to find the number of features we need for a better accuracy as well as the best ones among them. The accuracy scoring was proportional to the number of correct classifications. Then, the result was 17 as the optimal number of features was with 5 fold cross validation. Fig. 3 shows the number of features and the corresponding cross validation scores. The features selected are: Age, BW, GA, APGAR1, APGAR2, SAO2 (min, max and avg), Respiration Rate (min, max and avg), BP Cuff [Systolic] (max and avg), TIW (min and avg) and FIO2 (min and avg).

The second solution, which is the tree based feature selection, is more flexible in the final choice of features. In fact, a score specifying the importance of each feature is calculated and the choice is made based on this importance. Thanks to this principle, many datasets can be generated and used later with others classification algorithms. A further advantage of this solution is the ability to implicate physicians in decision making about relevant features apart from the importance score. Table II shows the list of the 31 selected features according to the importance for the purpose of classification and based on a threshold equal to 0.01 and physicians opinion.

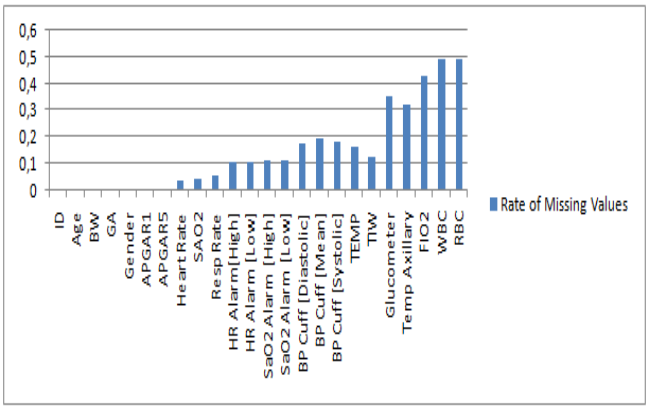

Fig. 2. Most Frequent Variables.

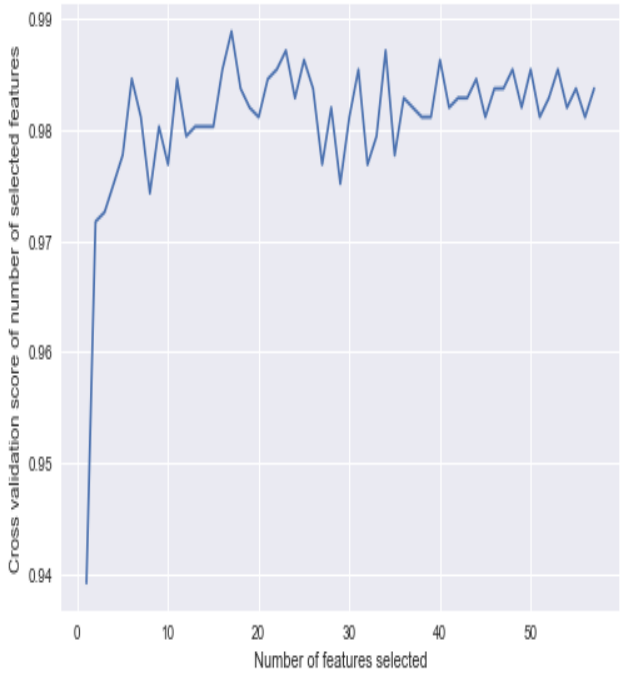

Fig. 3. Cross Validation Score of Number of Selected Features in RFECV.

TABLE. II. LIST OF 31 SELECTED FEATURES BASED ON FEATURES IMPORTANCE METHOD

Features	Description
AGE	AGE
GA	Gestational Age
BW	Birth Weight
APGAR1	APGAR for 1st 1 minute after birth
APGAR5	APGAR for 1st 5 minutes after birth
AVGHR	Average Heart Rate
MINSAO2	Minimum SAO2
MAXSAO2	Maximum SAO2
AVGSAO2	Average SAO2
MAXRR	Maximum Resp Rate
AVGRR	Average Resp Rate
MINSAO2AH	Minimum SAO2 Alarm [High]
MAXSAO2AH	Maximum SAO2 Alarm [High]
AVGSAO2AH	Average SAO2 Alarm [High]
MINBPCD	Minimum BP Cuff [Diastolic]
AVGBPCD	Average BP Cuff [Diastolic]
MINBPCM	Minimum BP Cuff [Mean]
MAXBPCM	Maximum BP Cuff [Mean]
AVGBPCM	Average BP Cuff [Mean]
MINBPCS	Minimum BP Cuff [Systolic]
MAXBPCS	Maximum BP Cuff [Systolic]
AVGTEMP	Average TEMP
MINTIW	Minimum TIW
AVGTIW	Average TIW
MINGLUCO	Minimum Glucometer
AVGGLUCO	Average Glucometer
MINTA	Minimum Temp Axilary
MAXTA	Maximum Temp Axillary
MINFIO2	Minimum FIO2
MAXWBC	Maximum WBC
MINRBC	Minimum RBC

To predict mortality based on data collected at admission and during the first 2 hours of stay into the NICU, several machine learning algorithms such as CART, LDA, KNN, LR, NB, RF and SVM were applied for patients' classification to identify mortal cases of those who are not. With 10-fold Cross Validation, for better representation of the whole dataset, LDA gave the best accuracy using the 31 most important features and LR gave the best accuracy using the 17 best features. The top three classifiers with 31 features are respectively LDA, LR, and KNN. The top three classifiers with 17 features are respectively LR, LDA and RF. But, according to accuracy, LR outperformed the others methods. Table III presents results of this work in terms of accuracy and standard deviation of each classifier based on sets of features generated by the two methods of features selection.

To summarize classifiers performance, another evaluation metric which is Receiver Operating Characteristics (ROC) is used. It's a kind of trade-offs between True Positive and False Positive error rates. And as observed in Fig. 4, LDA gave the best performance with 31 features (AUROC = 0.97) which was not the same case with the 17 best features, as shown in Fig. 5, KNN gave the best performance (AUROC = 0.97).

Finally, after classifying patients based on mortality, the Galaxy-X method was adapted to predict the patient death hours, of the classified cases as mortals, using 4 classes {1, 2, 3, 4} ∪ Unknown. The first class is that of patients whose mortality occurs between 8 and 24 hours after admission. Class 2 is composed by patients whose mortality takes place after one day of admission i.e. between 24 and 48 hours. Class 3 comprises patients whose mortality hour occurs after two days of admission meanings an interval equal to] 48, 72] hours. Class number 4 comprises patients whose mortality happens after 72 hours of admission to the ICU. The Unknown class is the last one. It encompasses patients whose mortality can happen at admission or during the first hours of admission (0-8).

It also contains misclassified patients as mortals. With Leave-P-Class-Out-CrossValidation (P=2), the f1-score of Galaxy Random Forest was 0.87.

TABLE. III. CLASSIFIERS ACCURACIES WITH 31 FEATURES AND WITH 17 FEATURES

	Classifiers with 31 important features		Classifiers with 17 best features	
Classifier	***Accuracy***	***StDev***	***Accuracy***	***StDev***
LR	0.940260	0.024331	0.956526	0.020104
LDA	0.947435	0.034886	0.954740	0.020186
KNN	0.931136	0.011005	0.922078	0.024524
CART	0.916688	0.028325	0.916623	0.033671
NB	0.793766	0.069147	0.931169	0.013546
SVM	0.931136	0.013683	0.923929	0.025387
SVM_RBF	0.931136	0.013683	0.923929	0.025387
SVM_POLY	0.896753	0.032194	0.918442	0.029643
RF	0.931071	0.022867	0.943864	0.028626

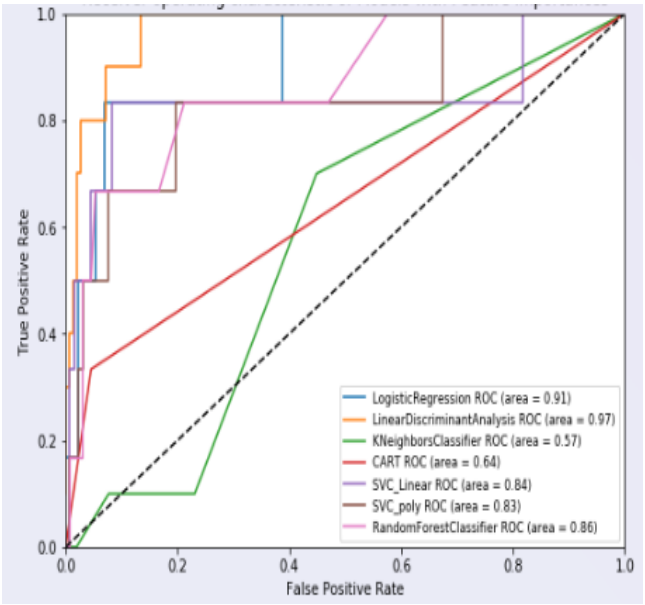

Fig. 4. ROC of Models with 31 Features.

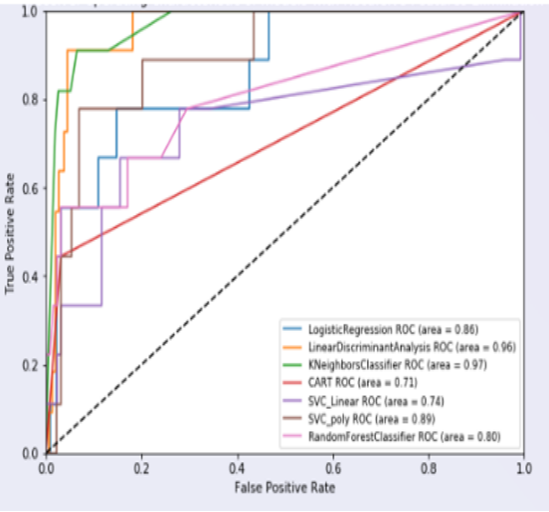

Fig. 5. ROC of Models with 17 Features.

V. Discussion

Scoring systems were helping doctors to calculate illness severity or mortality risk. In addition to these systems and for years, another alternative has emerged and has proven itself in the prediction of panoply of outcomes within the ICU. It is the machine learning techniques. They seek to help doctors make the right decisions at the right time.

Expecting CRIB II, which predicts neonate mortality after the first hour of admission to the ICU; these models predict mortality over a time span of 12 to 72 hours or more. It's in this context that the present work fits. Indeed, it aims to explore short-term mortality prediction after admission into the NICU. This prediction is important and has great impact on decision-making to reduce costs and to improve the resources management in these parts of hospitals where patients with the most critical health conditions reside.

The used database is the MIMIC-III, which houses different types of data of 7.867 neonates including 66 cases of mortality. From this initial dataset, data of 800 patients having age <28 days and only one admission to the ICU were selected. The data collected, include 7 general descriptors (ID, Gestational Age, Birth Weight, Gender, Age, Apgar 1 min and Apgar 5 min) collected at admission and time-series variables collected in the first two hours of NICU admission. Missing values and imbalanced classes were problems we encountered during the build of the model due to the very early time of data selection. After that, we used Features Importance and Recursive Features Elimination with Random Forest Classification to select the most relevant features. The second step of this work was the built of the mortality prediction model by testing an ensemble of machine learning techniques with the two sets of features generated in the previous step in order to find the best performing classifier. The best performing classifier with the 31 most important features was LDA. And KNN was the best performing classifier with the 17 best features. LDA was the one kept. The last step of the present approach for short-term mortality prediction was the built of the mortality hour prediction model based on a dataset containing only cases classified as mortal in the second step. Galaxy-RandomForest was used to build this model.

With an accuracy equal to 0.95, an AUROC equal to 0.96 with 17 variables and an AUROC equal to 0.97 with 31 variables LDA outperformed scoring systems such SNAP (AUROC=0.90), SNAP-PE (AUROC=0.93), CRIB (AUROC =0.90) and CRIB II (accuracy=0.867). Moreover, LDA outperformed the state of the art classifiers like SVM, RF, NB and CART and this was a very interesting outcome of this work from a machine learning perspective.

VI. Conclusion

Predicting outcomes in medical context based on machine learning techniques is the alternative that has gained ground compared with traditional solutions based on scoring systems. This is due to limitations of the latter and advantages and flexibility offered by recent solutions. Among these outcomes, mortality is one of the most predicted one especially in ICUs. Thus, this work fits into this context by proposing a new approach for short-term mortality prediction in NICU.

Through this work, three important results can be specified. First, to our knowledge, for short-term neonatal mortality prediction based on machine learning techniques and using time-series variables, it's the first work in this field after only 2 hours of admission into the NICU. Second, in terms of time and AUROC, it compares favorably with the state of the art classifiers (RF, SVM, CART and NB) and scoring systems (CRIB, SNAP, SNAP-PE, SNAP-II and SNAPPE-II). Finally, predicting death hours with Galaxy-Random Forest. This method can detect misclassifications and move them to the unknown class which can ameliorate the classification performance.

This work is an opportunity to consider the integration of prenatal data from mother and baby during pregnancy as these may be available at the child's birth and will not delay the prediction time. This is a perspective that can be implemented in future works in order to improve results. The establishment of a decision support system for short-term mortality prediction in NICU based on our proposed approach is another perspective for the present work.

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Unmanned Ground Vehicle with Stereoscopic Vision for a Safe Autonomous Exploration

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***Abstract*—At present there are several systems in cars that provide assistance to the driver and the tendency is that these systems are increasingly efficient and that for their operation do not require the intervention of the driver. Computer vision is relevant in this sector due to the contribution it provides, for example, through the treatment of images algorithms are designed for the detection of objects, pedestrian detection, traffic signal detection, one lane tracking and assistant parking.In this work we present an Unmanned Ground Vehicle system through Computer vision specifically Stereoscopic vision, through a sensor we obtain a disparity map that allows us to quantify the depth of each point of the captured image. The system captures an image of its environment that through internal processing of the sensor, returns a disparity map as data, which is processed by an algorithm that allows the system to navigate in a region of the space in which it is positioned for Autonomous Exploration.**

***Keywords*—Unmanned ground vehicle; stereoscopic vision; computer vision; autonomous exploration**

I. Introduction

In modern society, automobiles are of great importance and is that most citizens own a car, in 2016 5,725,574 motor vehicles were registered in circulation in Mexico City with a population of approximately 8,918,653 inhabitants. However, there are a lot of car accidents every day. These accidents in many cases are due to lack of driver attention, fatigue, drowsiness, consumption of harmful substances, stress caused by living in urban areas with overpopulation such as Mexico City, among other factors. And in 2016, 11,449 land-based traffic accidents were recorded in Mexico City, and governmental data reports that around 3,500 people die every day on the roads. In urban and suburban areas of Mexico only in 2016 there is a record of 4,559 people dead and 97,614 people injured; for traffic accidents.

At present, systems implemented in automobiles are developed to reduce car accidents, through different types of sensors that allow quantifying variables such as the distance of objects that are in the vicinity of a car. This allows the car to make decisions to control its speed and direction among other variables. These vehicles are called autonomous and are intended to provide assistance to the driver. Due to the great concurrence in the cities, autonomous systems are currently not prepared to make a decision according to each circumstance that may arise, they also have to process a large amount of information simultaneously from different sensors. So the development of software to solve these problems is in continuous development.

An image can represent a landscape, a caricature, a page of text, the face of a person, the map of Mexico, the culture of a country, a sunset, a sunrise and endless scenarios.

The digital image is the representation of that information in a numerical matrix of intensity samples that are reflected or transmitted through the objects and that is acquired through a CCD sensor. A CCD sensor contains a series of small light-sensitive diodes that convert light into electrical charges (photons in electrons) each CCD diode captures each element that makes up the image (Pixel).

Through the images you get a lot of information about the environment as colors and shapes. Currently it is possible to estimate the depth of objects that appear in a captured scene. As the human visual system does, through stereoscopic vision (Fig. 1), we have a perception of three-dimensionality due to the difference between the images captured by the right eye and the images captured by the eye left in this way the human being is able to appreciate different distances and volumes in the environment.

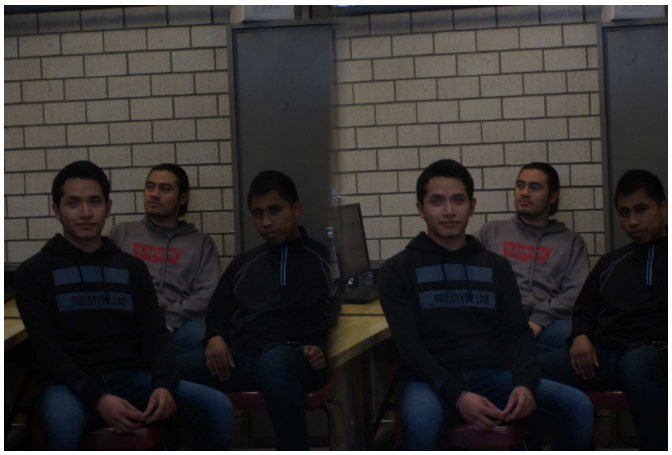


Fig. 1. Stereoscopic view.

One way to estimate the depth of each of the points in an image is by calculating the disparity, which is to measure the difference in position between two images captured by two cameras with similar characteristics, this difference or disparity is inversely proportional to the depth in the scene. To estimate the disparity, it is assumed that the scene is static, that is, that the visible objects do not change their position, nor suffer deformations. Once the disparity is estimated using one of the stereo images as a reference, an image with these values is generated, which is called the disparity map. The depth can also be quantified by means of the structured light technique that consists of projecting a burst of infrared beams of light that are captured by an infrared camera, and the depth is estimated by the distortion suffered by the projected light beams [1]

At present there are depth sensors like the one we use in this project that provides a disparity map, using the structured light technique Fig. 2.

Through image processing, algorithms implemented in autonomous navigation systems are designed, for example, object detection algorithms, pedestrian detection algorithms, traffic signal interpretation algorithms, algorithms for tracking single-lane lines, algorithms for measure the depth of the objects present in a scene, among others.

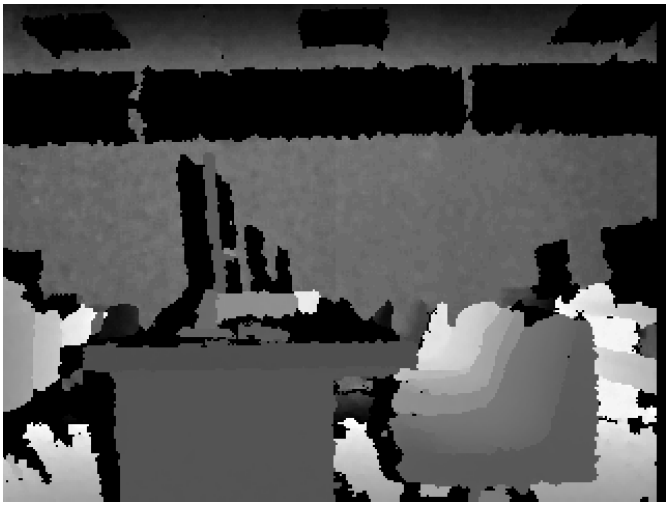


Fig. 2. Disparity map obtained using the ASUS Xtion Pro sensor.

This project presents an object detection algorithm to increase the autonomy of a mobile system, decreasing the probability of colliding with an object in the environment. The parameter to consider is the depth, which gives us the disparity map.

The depth sensor used in this project processes an image of the environment in which the autonomous system is located and as a result shows a disparity map. Specifically, the sensor captures the images at an effective distance of 0.80m to 3.50m, this implies that the system can not capture objects that are between 0 cm and 80 cm away from the sensor. As a solution to this limitation, an ultrasonic sensor is adhered to the system in the front of the vehicle, thus the system is able to detect objects that are before the field of vision provided by the sensor. To expand the effectiveness of this solution, a greater number of ultrasonic sensors is required to have a greater coverage of the environment.

Imaging is done when a sensor records the radiation that has interacted with physical objects. There are different models applied in the technology for the formation of images. One of these models is the geometric model that describes how three dimensions are projected in two. This means that it is possible to quantify the depth between the lens of a camera and the objects that appear in a captured scene.

For the development of computer vision algorithms in 3D, techniques such as monocular vision, stereoscopic vision consisting of an arrangement of two cameras with similar characteristics that take into account the epipolar geometry are used. These techniques aim to generate a map of disparity, disparity information is the process of equalization, where moves from the use of large disparities in areas of low resolution to the use of small disparities in high resolution areas.

This work is divided in another five sections: Related works, Theoretical Framework of Autonomous vehicles, Autonomous ground navigation system, Experimental Results and Conclusions.

II. Related Works

The car covers an important need in today's society, the need that people have to travel, and is that every day the individuals of a society have to move to a large number of destinations such as workplaces, schools, hospitals, even have the need to move to other cities. Because in the transfer the safety of people is at risk, automotive systems are constantly evolving each of its subsystems. And is that since its inception seeks that cars provide greater comfort and safety to the driver.

It mentions the electric ignition, ABS braking system, electronic injection, air bags, navigation system and power steering as the main improvements that have been integrated into a car. Currently, the trend is to develop smart cars with the ability to navigate, brake, avoid collisions and hazards on their own.

Artificial vision is an area of artificial intelligence that has a large part in the development of intelligent cars because it allows analyzing through images a large amount of information about the environment in which a system can be located. Through computer vision we can detect objects, colors and the distance at which an object is located with respect to a camera. Below are several advances of autonomous systems that use computer vision developed in the research and industry sectors.

Tesla is a company focused on the design of electric sports cars founded by Elon Musk in 2003. This company in the design of their electric cars has equipped them with an autonomous driving system called Autopilot [2]. As in the S model, Tesla offers an automatic pilot that drives at a speed commensurate with the traffic conditions, parks autonomously, has the ability to maintain or change lanes. Its system is composed of 8 cameras that provide a 360 degree view around the car, with a range of up to 250 meters, a front radar with improved processing provides additional data about the world with a redundant wavelength that allows you to see through of intense rain, haze, dust; twelve ultrasonic sensors that complete the vision of the cameras, allowing the detection of solid and soft objects. To understand this data, he uses an integrated computer running a neural network developed by Tesla for his visual processing software, sonar and radar.

This system provides a unique view of the world to which a driver could not have access, since it sees in all directions simultaneously and at wavelengths that go beyond the human senses, Fig. 3.

The Audi side assist is a system designed to warn drivers of dangerous situations when changing lane. Two radar sensors located on the rear bumper, which operate on the 24 GHz frequency, control the area parallel to the vehicle and also the rear area up to a distance of 50 meters. A high-speed processor analyzes the collected data. This system developed by Audi to help the driver to keep the vehicle in his lane. The signaling

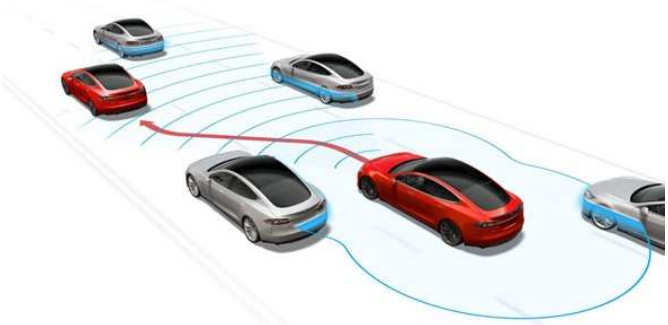


Fig. 3. Tesla Autopilot.

of the lanes is detected by a camera and defines the position of the vehicles with respect to them, Fig. 4.

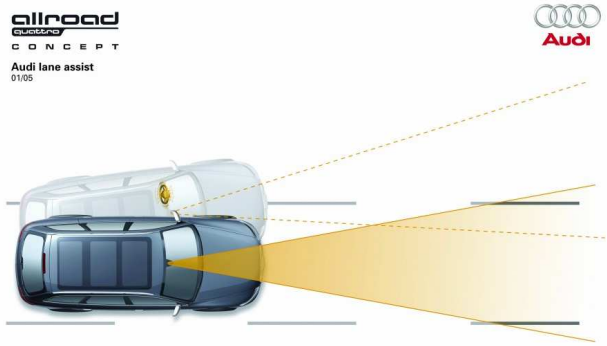


Fig. 4. Operating scheme of Audi Lane Assist.

The current interest of institutions and industry in systems capable of making driving safer has created a new line of research that seeks to address the issue of independent driving as well as computer vision, so that some of the projects developed by researchers from various organizations.

On the one hand, Combining Raspberry Pi and Arduino to form a low-cost, real-time autonomous vehicle platform proposed by Ryan Krauss in [3]. This project focuses on the creation of a low cost autonomous vehicle using Raspberry Pi, Arduino and the chassis of a juice robot. The Arduino platform handles the control laws which are executed in real time. While the raspberry pi is responsible for computer processing, a web interface and the transmission of data wirelessly. The robot has sensors to follow lines and implements a PID control to carry out its displacement, Fig. 5.

On the other hand, Real Time Obstacle Detection For Mobile Robot Navigation Using Stereo Vision is a project proposed by Sunil B. Mane and Sharan Vhanale in [4], security analysis and trends in which they perform the detection and evasion of obstacles through an algorithm. Using a passive stereoscopic Kinect camera, Fig. 6.

The fundamental idea on which they are based is to find a depth map of the image obtained by the Kinect and assign it to coordinates in the real world. The device used to achieve this is the raspberry pi 2 with which the video capture is achieved with a speed of 30 fps.

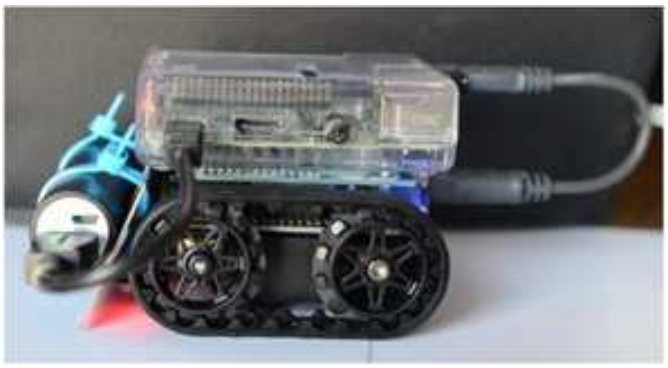


Fig. 5. Vehicle presented at the American Control Conference by Ryan Krauss in [3].

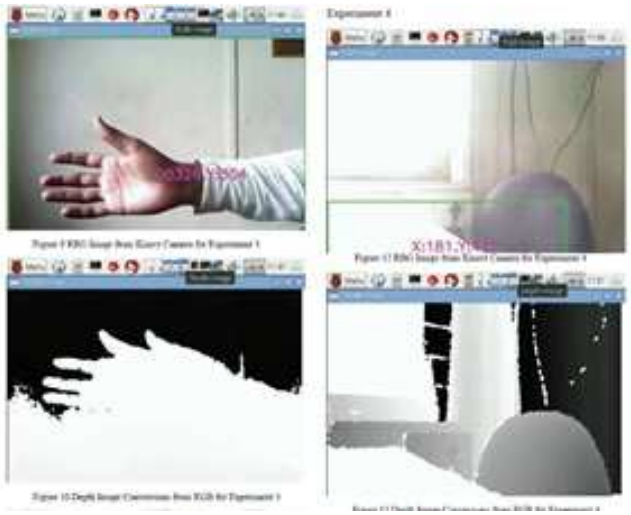


Fig. 6. Object detection using stereo vision together with Kinect [4].

III. Theoretical Framework of Autonomous Vehicles

This section will describe the hardware and software tools used for the development of the prototype as well as the general concepts necessary to facilitate its understanding.

A. ASUS Xtion Pro

Sensors such as the Xtion Pro are capable of capturing and processing gestures in real time, which makes them ideal for robots that must react to objects in motion, Xtion Pro uses PrimeSense's depth sensor technology. Table I shows the main features of this sensor. The company is known for the implementation of structured light or light coding in the infrared spectrum near light, it is an alternative to stereo camera systems that reduces costs because existing hardware can be used at low price [5].

TABLE I. ASUS Xtion Pro sensor specifications

Effective distance	0.8m to 3.5m
Field of view	58H 45V 70D
Resolution	QVGA(320x240) and VGA (640x480)

The Xtion Pro sensor only has one sensor to process the infrared light, the Xtion Pro-Live sensor includes an RGB sensor for taking photos and videos. In this way the development

of solutions for implementations in computing, where a RGB camera is useful and preferable. In the development of this project, an RGB camera is not necessary because a camera gives us the requirements in the object detection solution.

Structured light is a common and economical method to obtain depth data. A light pattern is projected and recorded with a CMOS sensor. By distorting the pattern, the depth can be calculated. Most structured light sensors change the pattern several times in a capture frame to get more accurate results. Due to the use of light patterns, structured light sensors only produce adequate results in interiors and environments with controlled lighting conditions. In the case of PrimeSense sensors that produce interference patterns in the near-infrared of light can influence the performance of the sensor.

Structured light projects light patterns to generate synthetic textures, this technique makes use of a light projector and a camera, that is, a light source and a receiver of light. The laser light source is placed at a known angle with respect to the object to be illuminated and to the camera. To perform a 3D inspection of an object, a line of light is projected. The distortions in the line translate into variations in height. From here you can detach a 3D form detecting the lack or excess of material or get to do a three-dimensional reconstruction of the object. The depth information is acquired from the relative displacement of the different points of the light line by the simple line method.

B. Open NI Framework

Open NI (Open Natural Interaction) is a multilanguage, multi-platform working environment that defines the APIs for writing Natural Interaction (NI) applications. OpenNI provides a set of Apis to be implemented by the sensor devices, and a set of APIs to be implemented by the middleware components. OpenNI allows application developers to follow real (3D) scenes using data types that are calculated from the input of a sensor (for example, representation of a complete body, a matrix of the pixels in a depth map).

The OpenNI framework is an abstract layer that provides the interface for both physical devices and middleware components. The API allows several components to be enrolled in the OpenNI framework. These components are called modules, and are used to produce and process sensory data. In Fig. 7 the layers that make up OpenNI [6] are shown.

Top: represents software that implements natural interaction applications.

The middle part: Represents OpenNI, providing communication interfaces that interact with both the sensors and the middleware components, which analyze the sensor data.

The bottom part: Shows the hardware devices that capture the visual and audio elements in a scenario.

The modules supported are:

- 3D Sensor
- RGB camera
- Infrared camera
- Audio device

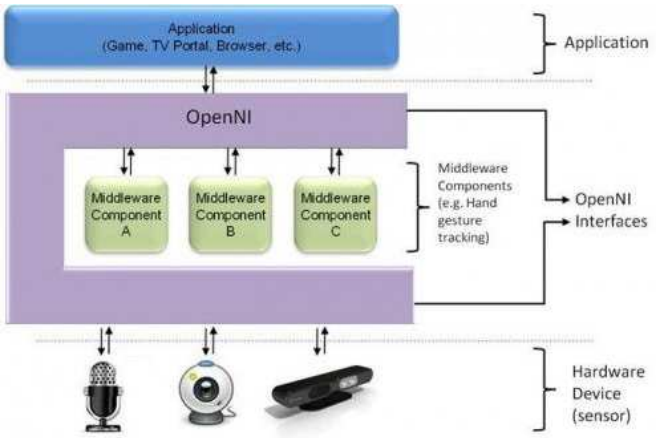


Fig. 7. Hardware devices that capture the visual and audio elements in a scenario.

C. HC-SR04 Sensor

The HC-SR04 (Fig. 8), is a sensor of distances by ultrasounds able to detect objects and calculate the distance to which it is in a range of 2 to 450 cm. The sensor works by ultrasound and contains all the electronics responsible for making the measurement. The HC-sr04 sensor consists of an emitter and an ultrasonic receiver that work at a frequency of 40KHz [7].

Fig. 8. Ultrasonic sensor HC-SR04.

The principle on which it bases its operation consists in generating a sonic wave in the emitter by means of a pulse when it hits an object, this wave is reflected towards the sensor and is recorded by the receiver. By means of the reflected wave it is possible to detect an object by measuring the time elapsed since the wave is transmitted in the air, through the *trig* pin until it is received in the echo pin. And as the speed of sound is equal to 343 m/s. With this, the HC-SR04 sensor quantifies the distance to which the sensor objects are located.

D. RASPBERRY PI3

The Raspberry Pi is a single-board computer (that is, it has all the components integrated in a single board) and a low-cost computer developed by the Raspberry Pi foundation in the United Kingdom with the aim of promoting the teaching of science in the schools Over time, the Raspberry Pi, together with the Arduino microcontroller board, have become a benchmark in the world and in the development of devices for the Internet of Things [8].

The Raspberry Pi3 has a quadcore processor much more powerful than the previous models, it also includes a Wi-Fi 802.11n and Bluetooth 4.1 which facilitates the connection to wireless networks. It includes interfaces such as an ethernet port to connect the Raspberry Pi via cable, an HDMI port

that allows the connection of a monitor or TV, an audio jack output and is powered by a mini-USB connector. It includes the GPIO pins, which are used to connect the Raspberry PI to the sensors and actuators. It is also possible to connect the PiCam, the official Raspberry Pi video camera, and a monitor with DSI connection, Fig. 9.

Fig. 9. Raspberry Pi3 board.

IV. Autonomous Ground Navigation System

Explained the existing elements to develop the project and with the established work environment. In this section we will explain the operation of the system and describe in depth the methodology used for the project.

In order to implement the computer vision algorithm it was necessary to build a system whose particular characteristics in terms of hardware are the following:

- 4 moto-reducers B01 1:48.
- 4 rubber wheels.
- 2 acrylic chassis.
- 6 spacers of 3.5cm.
- Driver CON1298 (H bridge).
- Ultrasonic sensor HC-SR04.
- Asus Xtion sensor.
- Raspberry Pi3 with case.
- LiPO battery from 1500mAh to 11.1v.
- Power Bank 2200mAh with output from 5v to 1A.

Whose most relevant elements are illustrated in Fig. 10 as follows:

The functions of each element that makes up the system are described below: The structure of the prototype that includes the motors, the wheels and the acrylic chassis was chosen because its purchase was made in a kit of pieces to assemble small and according to the hardware elements that were required to be integrated into the project. This option was preferred over buying a toy with the same characteristics because in this way we would be aware of the limitations of our hardware and we could integrate all the elements in a better way.

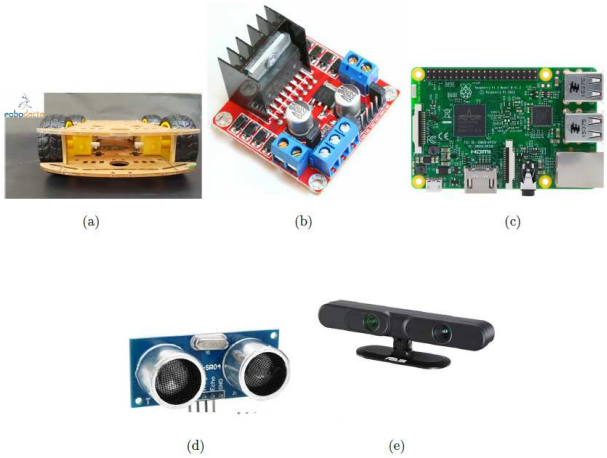


Fig. 10. Project elements, (a) Prototype chassis, (b) Driver CON1298, (c) [Raspberry Pi3, (d) Ultrasonic Sensor, and (e) Sensor Asus Xtion.

We decided to choose the CON1298 Driver for our system because it provides us with a tested and assembled H bridge, which saves us time in designing the control system for the prototype engines. The use of the driver is justified due to the need to send movement instructions from the Raspberry Pi3 to the prototype engines at different powers. This means that the instructions coming from the Raspberry Pi3 are not sent with enough power to move the motors directly, so an intermediate amplification process is needed, provided by the CON1298 Driver.

The HC-SR04 ultrasonic sensor was used in order to provide the prototype with an additional point distance measurement. This model was specifically used due to its great commercialization, its low cost and its extensive documentation. Regarding the computer vision sensor we decided on the ASUS Xtion sensor above the Kinect v1 sensor because the latter requires an additional power supply provided by an eliminator since it has additional features to those of the first mentioned sensor. The project required an infrared camera only and the Kinect sensor, in addition to providing an infrared camera, has an RGB camera, microphones arrangement and sensor adjustment motors. Therefore, its dimensions are greater than those of the ASUS Xtion sensor and its characteristics exceed those needed for the project.

For the embedded system it was decided that our best option was to use the Raspberry Pi3 development card above other options on the market such as Arduino, Beagle Bone, FreeScale, etc. Since this card, having an ARM technology processor, allows us to load a complete operating system based on a Debian distribution, as is the case with the Raspbian distribution. And with this execute more robust instructions as they are:

- Handling different USB ports.
- Higher processing power and shorter response time.
- High level programming.
- Use of concurrent programming to optimize the use of cores.

- Use of serial communication to communicate with the device.

This card when operating with an operating system eliminated the need to design the software from scratch. When using another card such as Arduino, we would have had to design all the necessary software blocks, such as reading the camera, the serial communication system to send instructions to the system, the processing of the images and the sending of control instructions to the motors. While with the Raspberry Pi3 we focus on assembling the blocks needed to perform sensor capture and serial communication to communicate with the system. Allowing us to focus on how to pose the algorithm to process the images and perform the control tasks of the prototype. top bottom The assembly of the hardware elements were arranged according to the scheme of Fig. 11.

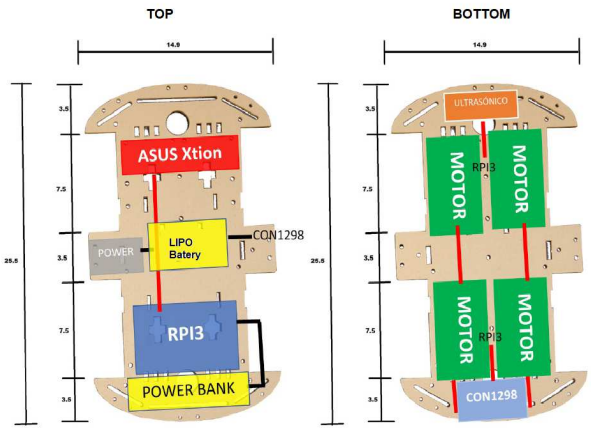


Fig. 11. Construction plan of the prototype divided into 2 parts.

Once all the hardware elements mentioned in the upper part are assembled, we obtain a system that as a whole has the following general characteristics:

- Vehicle with 4-wheel drive.
- Inclusion of a Raspberry Pi3 as an embedded control system.
- Asus Xtion as a vision system.
- Wifi connection.

The prototype of physical form is illustrated in Fig. 12 as follows:

Fig. 12. Final Prototype.

The system is constituted in two fundamental parts, the one of artificial vision and the one of control of the motors. Logic and power stage respectively. Within the artificial vision a redundant ultrasonic sensor is included to have a greater security in the movements of the vehicle because the ASUS Xtion sensor works in a range of 0.8m to 3.5m so the prototype has a blind spot of 0.8m that it is compensated by the ultrasonic sensor positioned at its center, Fig. 13.

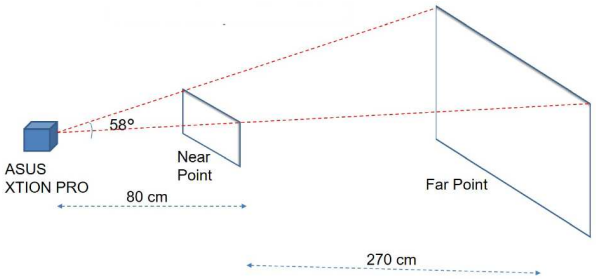


Fig. 13. Operating ranges of the ASUS Xtion sensor.

The prototype is capable of being remotely controlled from a computer thanks to the use of an access point where the embedded system connects like the computer. With which you can establish a communication between them using the SSH protocol integrated in the distributions based on Debian. This system has two independent power supplies. One feeds the control phase, while the other feeds the central computer.

The motors are connected in a series arrangement according to their position. This implies that the two motors on the left side are connected in a series, like those on the right side. So the voltage of the motors is divided into two while the current is not affected. The images captured by the ASUS Xtion sensor are processed in the following way:

1) As an initial step a capture is taken through the ASUS Xtion sensor, Which is illustrated in the image of Fig. 14(a).

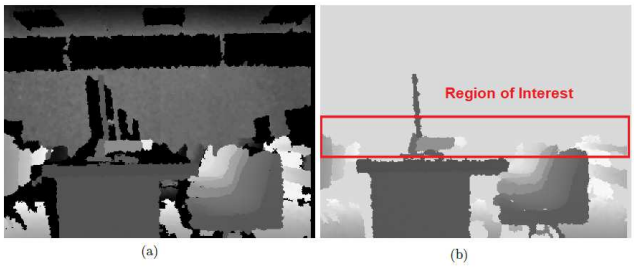


Fig. 14. Disparity map taken with (a)the ASUS Xtion and (b) thresholding.

2) The image obtained by the sensor has too many dark regions so it is necessary to use a thresholding of the image in order to eliminate the noise present in it. The result after the thresholding is shown in Fig. 14(b).
3) An image of the area of interest is obtained according to the limitations of the prototype, red box in Fig. 14(b).
4) Once the work image is obtained, it is divided into regions of interest. This is left, right and center image, Fig. 15.
5) The three images are processed by independently traversing the pixels of each one and the number of pixels less than 60 is counted. Since it was found that at 80cm from the camera the pixels are shown with

(a) (b) (c)

Fig. 15. Regions of interest of the image captured by the sensor, (a) Left, (b) Center, and (c) Right.

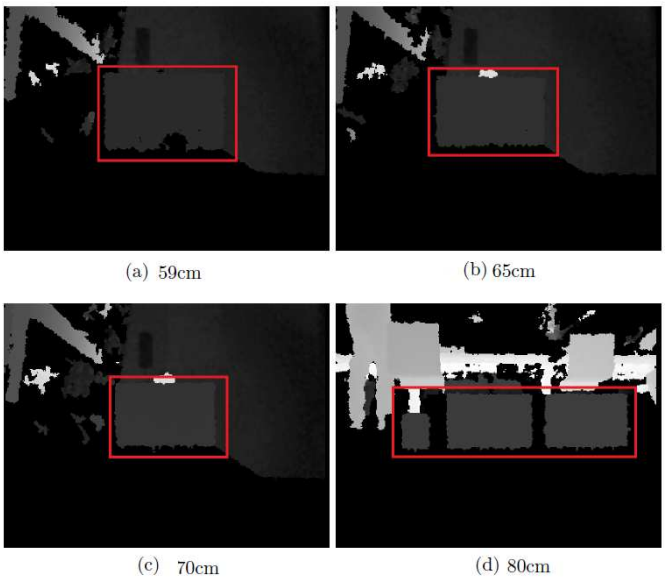
an intensity of 60. Therefore, if a pixel is registered below this value, it will indicate that the pixel is too close.

6) Once the number of pixels that are too close is quantified, validations are made to know which regions have less than 5% of the total of their pixels. Areas that have more than 5% of nearby pixels will be discarded so the prototype can not move through that area.

When comparing both images in Fig. 14. We can observe that the original capture of the sensor shows a greater depth than that obtained through the thresholding although due to the fact that the project makes the decisions with the closest images. The visualization of areas too far from the sensor becomes irrelevant since the processing of the images considers only the areas closest to the ASUS Xtion sensor.

Once the hardware elements are combined using software, the system is able to take disparity images and save them in documents with PNG extension. A methodology was designed to know the capture system and with this to know how the division should be done in areas of interest. Next, the methodology used will be explained:

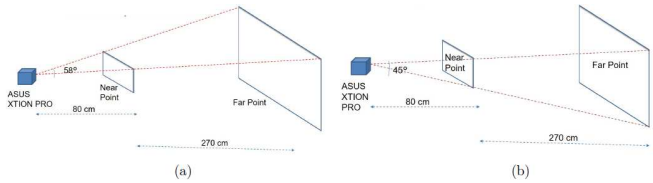
1) Captures of objects at different distances were taken with the purpose of knowing at what distance the objects were visualized more clearly, Fig. 16, the objects captured at the specified distance are observed in the red rectangles. In the different captures made it was observed that at 80cm the best objects were obtained since at closer distances the objects sometimes appeared with black regions inside them, which would throw us an error in the decision of the free zones.
2) Once the distance to be used was chosen, we proceeded to delimit the dimensions of the image taken, that is to know at 80 cm of what size the frame of reference is obtained, this is illustrated in Fig. 17. These values can be obtained theoretically based on the fact that an isosceles triangle is formed between the camera and the reference frame, which can be decomposed into two right triangles, and knowing the angle of vision of the camera provided by the manufacturer, it will be possible to determine the dimensions of the reference frame theoretically.
For the assembled system it was decided to obtain the frame of reference in a practical way taking advantage of the capture of the images, This is shown in Fig. 18. In which 2 objects were placed at the ends of the capture as can be seen, then the distance between them was measured physically. This same process was carried out vertically taking as a reference the feet of a person. With which the results shown in Table II were obtained.



(a) 59cm (b) 65cm

(c) 70cm (d) 80cm

Fig. 16. Capture objects at different distances from the sensor.



(a) (b)

Fig. 17. Range of vision of the prototype, (a) horizontal and (b) vertical.

Fig. 18. Obtaining dimensions at 80cm.

Therefore it is concluded that at 80cm distance a pixel represents 1.17mm of the real world. To obtain the region of interest, an object of the same dimensions of the prototype is placed in front of a wall 80cm away. The image is analyzed with MatLab to determine the region that the object occupies in front of it.

TABLE II. REFERENCE FRAME CALCULATED IN A PRACTICAL WAY.

Distance(cm)	Length(cm)	Height(cm)	pixel
80	75	45cm	1.17mm
152	158		2.46mm

The object is not visually easy to identify due to its thickness but using a computer program the depth difference exists. Based on these parameters, the regions of interest described in previous sections are taken.

V. Experimental Results

The autonomous navigation system depends on the depth sensor, which integrates an infrared camera whose performance depends on the intensity of light in an environment. Below are three experiments that indicate under what conditions the functionality of the system is acceptable. Based on these experiments is that the future work of the work is considered.

A. Environment with Illumination greater than 850 lux

For this experiment the prototype was placed on a concrete slab with various obstacles with the sunlight directly incident on it and a measurement of the lux of the medium was made, which gave a measurement of 850 lux approximately at 12:00 noon. The algorithm was put into operation and it was observed that the vehicle did not detect the objects and crashed against them. In this environment the disparity map that is obtained is shown in Fig. 19.

Based on Fig. 19, it is concluded that the burst of light beams projected by the depth sensor is in the same range of frequencies that sunlight provides, due to this the light is interfered with and the image obtained is in the white spectrum. This phenomenon is similar to that experienced by a person when he tries to look directly at the sun, without any type of protective glasses.

(a) (b)

Fig. 19. Illuminated image of 850lux, (a) Real capture image, and (b) Map of disparity obtained from Fig. 19 (a).

B. Environment with Lighting less than 10 lux

In this test the prototype was placed in a roofed environment with transparent sheets which let in enough light but without the direct incidence of the sun. The algorithm loaded to the embedded system was executed and it was observed how the prototype evaded the obstacles in a precise way. In this controlled light environment, when the illumination does not exceed 10 lux, the disparity map that is obtained is shown in Fig. 20.

In the disparity map obtained, a thresholding of the objects that appear in the scene captured by the depth sensor is observed. This parameter allows the functionality of the system to be effective because it indicates that the objects that appear in a scene are identified.

(a) (b)

Fig. 20. Illuminated image of 10lux, (a) Real capture image, and (b) Map of disparity obtained from Fig. 20 (a).

C. Environment with Null Lighting

For this experiment the prototype was placed in a room with very little lighting in which the lux meter showed a measurement of 0 lux in the room. The program loaded in the embedded system was started and the disparity map of Fig. 21 was obtained.

In a nocturnal environment you get the following disparity map. As seen in the image the prototype can recognize the objects that are in the room so the system works properly in dark environments.

(a) (b)

Fig. 21. Illuminated image of 0lux, (a) Real capture image, and (b) Map of disparity obtained from Fig. 21(a).

VI. Conclusions and Future Work

An autonomous navigation device was designed making use of artificial vision which is capable of making decisions regarding its direction making use of the capture of a disparity map and processing the images. The environment of autonomous vehicles and its history was analyzed in order to know its historical context in 2019, to know what projects exist and what tools are being integrated into commercial projects such as research to identify which areas could be worked on.

The hardware and software elements that were used for the project were defined, considering their characteristics in order to understand their operation and to know how they should be assembled within the system.

The methodology used in the project was analyzed with the purpose of documenting the advances and procedures implemented within it for future reference. Within this analysis it was concluded that the prototype is not capable of functioning in sunny environments because the sun's rays cancel out the infrared lights emitted by the ASUS Xtion sensor, which gives false-positive results in the processing of the images.

Although the project is fully functional and complies with the general objective stated in the Introduction of the

document, there are still several aspects that can be improved in order to obtain an improved version of it. For example the design of a communication system: a communication system based on IoT to link several prototypes and share information about their environment in order to know if there are possible collision risks between them can be designed.

Also, an analysis on the power stage: In-depth analysis of the power stage is proposed, that is to employ people specialized in control which can better model the power system and, if necessary, execute modifications in the hardware with in order to optimize the response of it. Similarly, better characterize the hardware elements to know all the limitations of this.

With the development of this project it was possible to learn about different pieces of hardware and software tools which were combined to establish a design platform on which one can work to test different computer vision algorithms, and even artificial intelligence with the purpose that students and researchers of the National Polytechnic Institute of Mexico (IPN) or other educational institutions can improve saving time in the design of the unified platform. With this tool raises a raid by Mexico and the IPN in the world of autonomous vehicles which are beginning to be the new line of research to be exploited worldwide.

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Privacy Concerns in Online Social Networks: A Users' Perspective

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***Abstract*—Social networking has elevated the human life to the heights of interaction, response and content sharing. It has been offering state of the art facilities to its users for a long time. Though, over the period of time, the systems have become quite matured yet alongside the benefits, multiple concerns of the user with regard to the privacy and information security also exist. Multidimensional threat spectrum to the Internet has also been posed to social networking tools. A lot of work is being done to understand privacy concerns in social networks. In this scenario, a survey of privacy concerns in online social networks is conducted. Risks, privacy issues, and threats have been highlighted that occurred in recent years, analyzing the targets of attackers, their methods of attack and measures taken to counter/manage these threats are the focus. A social network depends on the user, social network site/application and communication medium provider i.e. the Internet facility. Existing research contains domain specific research work regarding privacy issues in social networks; however, a comprehensive research work related to overall infrastructure of online social networks is missing. Development of a taxonomy of threats and categorization of frauds relevant to social networks is an important contribution of this survey. After completing a comprehensive research survey on privacy concerns in online social networks, a set of privacy guidelines is provided and open research challenges are highlighted.**

***Keywords*—Online social networks; information security; privacy; social networking; attribute disclosure**

I. Introduction

Researchers related to different research areas have analyzed the on-line social network (OSN) in different ways. User privacy problem has been considered as one of surveillance, institutional privacy, social or an individuals' privacy issue. Researchers made their understanding independently, however, OSN privacy research would benefit from a more holistic approach. Privacy and an individual's social network are viewed in a multifaceted relation. For example, at sometime we do not want to publish our information on the web, however, we want it to be accessible to a small number of close friends, and not to outsiders or unknown. At some other occasions, we are eager to share information with the public, but not to our friends. Social network analysis techniques describe the impact of different depth and strength of ties in an individual's social network and the importance of these ties in the flow of information across the network. Social engineering is a well-known practice in the information security domain in which confidential information is retrieved by manipulating legitimate users. This practice may be implemented on an online social network, like Facebook, very simply by sending friend request. Shockingly, it has high success rate, the friend request was accepted by 75,000 out of 250,000 unknown users, when sent using a programmed script on Facebook [1]. Teenagers as compared to professionals are very much influenced by social networking sites. Sometimes they represent some sort of addiction to social networking. They behave carelessly and share private data without realizing its effects on privacy [2]. Users conversations, like/dislike some time may help in deducing some results related to personal data. Studies have also been conducted to compare the behavior and response methods of male and female [3]. Majority of Facebook users are eager to publicize themselves [4] and their profile information is available to a stranger and their network of friends. Is there any proper way to make decision positively for joining an OSN [5]. The Internet and social media content sharing made tremendous developments, however, at the cast of one's privacy. Manufacturers of smart devices like LCD/LED TVs categorically warned users not to share anything private before their smart devices [6]. User awareness about handling Smart Devices, especially privacy sensitivity instead of information security measures [7], is actually core need of the time. Samsung Smart TV is one of the Smart devices whose privacy policy statement declares clearly about voice recording and transmitting it to a third party [8]. Mainly a user or group of users, Internet service providers, Communication medium and the Social Networking Application makes a Social Networking infrastructure. Details related to OSN such as its definition, methods, facilities, history, rise and fall of different OSNs are covered in [9]. Details about Social Networks and Network Structures are also explored. Different types of frauds, hacking / cracking activities, spyware, malware, and malvertising etc. have been in practice for capturing private data of user/(s) [10], [11], [12]. With the advent of new approaches in Web technologies, from Web 1.0 to Web 4.0, the Internet of Things, connectivity of heterogeneous devices and sharing of data among them may cause new dimensions of Privacy Risks along with Safety and Security aspects[13], [12]. Social Networking is actually a need of time, where its usage again needs a responsible behavior. It is the user, who is solely responsible for her data/privacy, a user himself has to take strong measures for the protection of privacy [14]. Data analysts have worked for data collection, categorization and establishing links among different users as well as a group of users, based on not only user profiles but also comments, uploads and like or dislike measures. This study categorically highlights concerns and important measures for users privacy [15], [16]. This survey is divided into different sections starting from privacy

understandings till providing some practical guidelines to be taken care while remaining on online social networks. Section II covers common concepts of OSN and its privacy, interaction vs surveillance, and parameters for user privacy. In Section III the need of limiting social network activities for privacy preservation is highlighted. Section IV provides taxonomy of OSN threats and its details in which threats and vulnerabilities in OSN are categorized in different classes and furthermore discussed in an information sharing approach. In Section V, a comprehensive discussion on issues after compromised privacy is carried out. Disaster after a compromised and how compromised privacy support in terrorism are also covered in Discussion part. Also privacy guidelines for secure OSNs are provided. Finally, Section VI concludes the paper.

II. Understanding OSNs

Pros and Cons of OSNs have been deliberated for a long time. Cyber Connectivity and Cyber Security, User Privacy and Anonymity, Cyber Bullying and Cyber Threats, Surveillance and Connectivity, Cyber terrorism and Cyber Warfare, are the areas of extraordinary interest in these days. Multidimensional attention has been given in terms of Information Sharing and User privacy in Online Social Networks. Research on OSNs can be expressed and categorized in the following sub-categories.

- Need for OSNs
- OSNs Models
- Information Extraction on OSNs.
- Privacy Leaks and Privacy Measures in OSNs
- Anonymous behavior of users
- User / Human Behaviors in OSNs
- Privacy Issues in OSNs
- Cyber Threats in OSNs
- Cyber Crime / Terrorism and Attacks using OSNs
- Miscellaneous trends and trend building approaches in different of OSNs

A lot of research work has been carried in this regards. A detailed literature review is carried out as under.

A. Need for OSNs

It is related to the use of Social media and how people are dependent on Social media. We can not avoid Social media but can use reasonably. The importance, utility, and dependency of social media is explained in [17].

B. OSNs Models

OSN models for information security and their usefulness comparison is described here. The concept of Total Utility, Social Welfare along with cost functions are introduced in information sharing and privacy in social networks [18]. Multiple social networking applications are very much in practice in different communities. Multiple social networking sites and applications are having heterogeneous architectures and functionalities. A need for a generalized architecture for different social networking sites / apps is suggested [10], [19]. A comparison of different defense systems and models is provided and an approach is proposed for identity theft attacks in social network sites. Because of the insecure Internet [20], users are always vulnerable to the misuse of identity and problems of remote authentication. A secure authentication and validation of authentication are crucial for remote transactions [21], [22], [23]. A social network model None of Your Business (NOYB) [24] is used to implement improved privacy settings which helps users to implement more security settings. Privacy-preserving techniques in different OSNs and their comparison is carried out in [25]. Authors introduced a new concept of end-to-end encryption, hidden social graphs and discarding incompatible devices in [26]. Privacy preservation in decentralized online social networks has been highlighted in [27]. In [28], a machine-learning based approach is presented for privacy-aware information-sharing in mobile social networks. Authors presented and evaluated a privacy-preserving information sharing system (SPISM) in an automated fashion to share different types of contextual information and for specific levels of detail. It is a system that may be used to further automate other systems in instant messaging like applications. Authors explored privacy issues in online social networks and proposed a k-degree anonymity to secure information on social networks using Data Collection, Reduce Node Degree, add Node Degree and add Noise Node. The study [29], critically highlighted the privacy leakage in data sharing using social networking sites. It describes that sharing photos and tagging a photo increases the chances of data leakage exponentially. A new technique i.e. rule-based photo sharing for securing data for social networking sites is suggested. Separating privacy settings for photos and profiles by introducing independent privacy settings for each attribute is covered in [30]. Another dimension of symmetry about the architecture of social networks is highlighted in [31]. An approach using architectural symmetry and functional harmony can eliminate diverse nature of social networks. Privacy risks in OSNs are introduced because of un-symmetric configurations across the OSNs. For highlighting the issue of privacy leakage, an inference attack for leakage of data privacy is introduced. A new approach known as PbD (Privacy by Design) principles is introduced for OSNs in distributed computing environments [32], instead of any framework or technique, it pointed out the lack of proper PIA (Privacy Impact Assessment) [33]. Authentication and access control always remained the core area of research in every computing system development [34], [35]. Involvement of the third party for certification of OSN applications is suggested in [36], [37]. The openness of OSN users and application capability for information classification is to be taken care of. There are multiple classes of adversaries for example inside attackers and external attackers or intruders, who use user social space and social interaction to get into user's information. Two types of OSN architectures i.e. Client-Server architecture and P2P architecture are in practice. The important aspect of user identity anonymity, user personal space privacy and user communication privacy are the top priority[38]. Protecting online social graphs, defense against Social Link Forging Attacks and defense against Node Identity Forging Attacks are suggested in [5] . Another data security approach for OSN content sharing especially photo sharing is described in [22]. It provides a concept of policy-based photo

sharing along with its demonstration.

C. Information Extraction on OSNs

The general attitude of OSN actors looks very strange sometimes [39]. There should be a clear understanding to handle a friendship request. A scripting technique was used to send automated requests for friendship to Facebook users. Out of 250,000 requests, author was successful in making 75,000 friends [1]. Tools exist for mining information from structured data[40], but in OSN data is not fully structured or unstructured. The authors exlore Semantic Web techniques for the collection of useful cyber security-related information from Social Networks. Analysis and storage of triples of RDF/OWL have been explored. OSNs are very much in practice in smartphones [41]. Mobile social networks (MSN) are providing real-time connectivity and content sharing. These MSNs provides datasets, and tools/techniques are available to find communities and groups in Mobile Social Networks [42] and other Online social networks [43]. A study carried out to analyze Facebook data using Netvizz application [44], [45]. The NetVizz application is covered in detail and the use of this application for data extraction and further use in different analyzing tools i.e. empirical analysis is discussed. Importance and utility of User Data Graphs and Social Nets are also highlighted. Extraction of Cyber security data from Linked Open Data (LOD) is also very much in practice. Semantics-based data extraction using RDF is suggested and an architecture is defined in [41]. Similarly, botnets are being used for data extraction from social networks [46], [47]. Neighborhood attack is another important concern of user privacy[48].

D. Privacy Leaks and Privacy Measures in OSNs

Data leakage of social network users is also a great threat. It is covered in [49], [50], [51], [52], [53]. These papers provide different methods for collecting identities, cloning and their use for criminal acts. Identity theft attack causes leakage of user privacy. Email ID is the only unique identifier which can cause disclosure of other information also. Three approaches for defending against Identity Theft attack are covered in [20]. Location disclosure is one of the most important privacy issues. Smart Phones provide state of the art Internet connectivity along with location information based on GPS and Internet-based location information. These Smart phones also provide updated social network applications with real-time connectivity and information sharing. Mobil share architecture is introduced to address location sharing problems in mOSNs [54], [55]. Improvements are suggested in location information gathering. Authors suggested that trusted and untrusted information providers should be classified and proposed the use of k-anonymity technique for information disclosure. Users depend on OSNs for interaction among their groups [36], [56], [57]. Basic four things that invite spammers are (i) controlling entity of the entire OSN (ii) well-defined interactions (iii) user Identity (iv) multiple interfaces of OSN providing different views [44]. Spams are spread on OSNs for collecting user activities and data, and a cause for privacy leakage [58]. Conventional coping and technological coping are suggested to protect against Identity Theft in [59]. A comparative study for consideration of conventional coping and technological coping is also provided.

E. Anonymous Behavior of Users

Users of Facebook and other SN applications, stay un-friended on the Internet. Positive, as well as negative concepts exists while remaining un-friended. Users may un-friend a few to reduce their friend's list [60], [61]. Staying hidden vs staying un-friended [62] is again another important research direction in social sciences. OSN users have different intentions to stay hidden or stay un-friended. A user staying hidden may be more dangerous than staying un-friended because of users shared content space, and in some cases, it may be otherwise. An exploratory study [63], [61] is carried out to determine users' emotional and cognitive response for un-friending someone on OSN. This is very much clear and an eye-opener for privacy researchers, where an individual's privacy is at great stake [60], [64].

F. User / Human Behaviors in OSNs

Human behavior and the way how a user responds to OSNs activities depends on specific class. Here, these classes are Age and Gender-based.

1) Age Factor: Social network users belong to different age brackets. But the majority of users belong to teenagers. In [24], authors made a mathematical analysis of teens activities and their concerns about privacy while remaining online. How their parents and guardians affect teens awareness about privacy? Since young adults are very much active on OSNs, therefore, neuroticism, extraversion, and online self-presentation among young adults occur. Comprehensive research has been carried out to analyze and understand these situations in [65].

2) Gender Factor: An interesting study provided in [3], authors explored dissimilarities in the behavior of men and women to handle the threats on social media. The main focus was the how and up-to what extent man and woman retaliate to threats, dislikes, rejections, etc. How users decide to join a Social Network? In [5], Data Mining, Group Analysis, Sensitive Attribute Inference development approaches for OSN are explored and a new Link Data Analysis approach is suggested.

G. Privacy Issues in OSNs

User authentication is the basic need for user data security. To handle identity theft and cyber-crime, [66] describes suitable authentication systems and parameters for a good authentication system. Use of biometric devices is also suggested. However, the issues of Biometric device utility and availability must be taken care. These biometric and other wearable sensors may not be available everywhere. Basic components of user authentication are User Identity and Password Credentials. Protecting login credentials is the responsibility of a user. But what are the measures to protect user identities? In [59], the coping perspective, threats related to user identities are covered. How to avoid misuse of user identity [67], parameters and methods required for safe use of identity in terms of financial loss, criminal activity, colluding attacks and identity cloning are described [68]. An analysis is carried for security challenges and vulnerabilities in software architectures of social networks. Mostly script based / programming attacks are emphasized in [69]. Smart Phones are now fully powered to connect OSNs. Privacy threats categorically related to mobile social networks

are covered in [69]. Threats and vulnerabilities in mobile social network applications and gadgets already installed in mobile devices may cause more privacy issues. Various security and privacy challenges in mobile social networks are discussed in [70]. A gesture assisted authentication proposed three research areas covering Gesture assisted secure information sharing, effective resistance to Sybil attacks (especially mobile based) and private information management based on the social context. An article about privacy in the use of Smart TV [6] uncovered a story about spying approaches and practices used in different models of smart TVs. Samsung Privacy Policy [8] - Samsung rejects the allegations of spying but accepts about data collection for voice commands and their proper recognition. This feature can be disabled also. Humanly, it is very difficult to confirm or authenticates legitimate social media account, a lot of research is required in this domain [71], [72].

H. Cyber Threats in OSNs

Cyber space is too vulnerable for its users as claimed in [73]. Threats arose in social networking sites are categorized based on their portfolios and solutions are also suggested [11]. Different aspects of threats in cyberspace in terms of software, hardware, and network and also outstretched [13]. Smart devices are the basic entities for smart cities. Smart devices are connected to each other using the Internet as a communication infrastructure. Different threats like leakage of user privacy parameters in smart devices and a need for meaningful debate for cyber-security challenges in smart cities is also highlighted. In cyber threats in social networking websites [14], user gathering comparison on different social networks is carried out along with user behavior & awareness level that affects controlling of user privacy. Highlighted security threats raised with the advent of new technologies especially in social networking, and few suggestions are made for user privacy. User awareness and narcissism techniques introduced for detection of Insiders Threats, Outliers, Text, Context, video, and other uploads analysis provide very useful inferences and deductions. In [15], a detailed study is presented for the importance of the privacy factor in OSNs. A survey for privacy in SNs is carried out and calculated the privacy quotient of users by using the naive approach [16]. A privacy Armor model is proposed to ensure privacy in the unstructured data by generating an alert for leakage of the specific / private term. Interaction and contact vs surveillance are the two bright faces of SNs. In [16], it is highlighted that social connectivity and surveillance are two important aspects of Social Networking Sites. A detailed study is carried out for concepts and common understandings of privacy.

I. Cyber Crime / Terrorism and Attacks using OSN

With the development and advancement of OSNs, data collection, analysis, collection and coalition of information is not a very big deal. Cyber Terrorism, nowadays, depends on online available information. In [74], authors provide different aspects of threats and terrorism using the Internet, also differences between Cyber terrorists and hackers. Cyberspace opens for all types of Internet and unfortunately used by miscreants. A detailed study highlights all the aspects of threats and terrorism using Cyberspace. The motives, targets and methods of attackers, levels of attacks, and activities, influences, and paybacks in cyberspace are highlighted in [59]. Different types of social networks are highlighted and based on these types, dynamic aspects of national security and threats suspected to national security by using SNs are described in [58]. Authors critically pointed Government organizations to take part and make policies on use and misuse of OSNs to counter miscreants. Identity misuse and representation of multiple identities by a single user is really a danger. Vulnerabilities, exploits in data communication and networks, its effects for data leakage and countermeasures are given in [75], [76]. The Sybil attack openness and dynamic nature of SNs, are more vulnerable, and these vulnerabilities are exploited by different attackers. One of the attacks launched on social networks is the Sybil attack. Its behavior and scheme of operations and mathematical analysis have is provided. Use of Sybil seeds and edges of graph are explored in [77]. Privacy setting can be enforced to allow communication /interaction/sharing among friends only. However, there are threats in which mutual friend based attack is launched as highlighted in [78]. Attribute disclosure is one of the Social Network attacks. An approach for security within social networks against attribute disclosure attacks is suggested in [79]. For privacy patterns, a measure for an attribute disclosure attack is provided when one succeeds in getting particular nodes identity. A detailed list of reported cyber-crimes using social networks data are given in [80]

J. Miscellaneous Trends and Trend Building Approaches in Different OSNs

Semantic Web is emerging and helping people to cope with interoperability issues. In [81], authors highlighted the importance of Semantic Web for interoperability, and how the large collection of vocabularies developed for Semantic Web affect user privacy and interoperability. The user may belong to only a single Social Network or may have its presentation on few or all available social networks. An activity comparison of users on three SNs is carried out and privacy issues in terms of data analysis, network analysis, account association leakage, network connection leakage, etc are discussed in [82]. Furthermore, removal of identities from public search engines, disabling of reverse lookup functions, and provision to create users own attribute lists/groups is explained.

III. Understanding the Privacy

User Privacy is concerned with the information of a user that he or she is not willing to share with all others knowingly or unknowingly. Privacy can be defined in multiple dimensions. The easiest to understand definition found is the right of the individual to decide what information about himself should be communicated to others and under what circumstances [82]. Different perspectives of user privacy in OSN is explained in [83] with very comprehensive detail. Another important aspect of privacy and security is taking the assessment and monitoring user privacy and security in social networks [84]. Privacy may be explored in terms of the following.

A. The Surveillance Perspective

Revolutions because of web-based social media are much popular and are under discussion similar to Facebook and Twitter revolutions in politics and democracy. International

moves for Internet Freedom and Right of Information also have greater impacts on OSN. Insecure Internet, identity theft, misuse of identity, mining identity-based information and exploration content space of a user generates surveillance concerns [63].

B. The Social Privacy Perspective

Analysis of an individual's shopping interests boosts economic revolutions and analysis of traveling and living information may strengthen the exploration of interests of society. However, along with all these benefits, individuals likes and dislikes, status and personal preferences may cause problems of social respect and security as well [49].

C. Parameters of Privacy

User ID, Password, DOB, Address, and Location, etc. are the basics of user privacy. Data mining and other network extraction, analysis, and drawing techniques help users to infer required information.

D. Limits for Sociality

A mechanism for suitable limits in Social Networking / Connectivity is missing. When a social network user posts something to his profile and then every one of his / her network can access the post, there is no way for a user to limit/hide posts for individuals. It is the established fact that people on OSN are not only social users. Directly or indirectly, knowingly or unknowingly, all are spying on each other [17]. The responsible social actor is the need of time. Some basic rules must be defined and practiced for social actors [85]. An expression generated on OSN for celebrating an event may cause a danger for the recipient. Similarly congratulating someone on any occasion may cause some serious family problems.

E. Privacy Issues in Social Networking

Sites for social networking like Facebook, Twitter & Google Plus have gained more popularity in recent years. Larger user-base and a large amount of information attracted the attackers and a potential channel is provided to be exploited. Most of the users try to prevent from such exploitations, however, attackers are more capable to overcome provided security measures by using diverse techniques. Users may not be aware of such threats or vulnerabilities that may include privacy issues, social networks spam, identity theft, malware, and physical threats. Very dangerous & deadliest attacks found in recent history are discussed in [86], [87].

IV. Taxonomy of OSN Threats

In this section, we propose the taxonomy of all possible threats shown in the Fig. 1. Four basic dimensions have been introduced to take care of threats to OSN as well as smart cities as explained in [13] and [14], similarly [59], [17], [20], [88], [89], [90]. Different types of threats have been found in the literature. These dimensions have further been divided into the following categories for clear understanding.

A. Infrastructure

OSN Infrastructure consists of a website/service hosted on a server, user application or website, central database and a communication channel i.e. Internet service [33], [26], [91]. Infrastructure threats can be further categorized into server-based threats, database threats and ISP/Internet-based threats. These threats are described as follows.

1) Server: Threats can damage servers partially or completely. Access Control, Viruses, Spam, Hacking, DOS, DDOS and Flooding (Unicor, etc.) are important dimensions. Location disclosure is also a great threat for OSN users. Weak access control allows unauthorized access to a server and can cause social privacy issues. Viruses can disrupt the infrastructure of a social network. The viruses can damage OSNs in several ways either by causing system failures or unwanted data leakage. These include Malware and Spyware etc. Spams are unsolicited messages that can disrupt the server and can cause data leakages. Hacking is a well-known server threat. An attacker who can get the server access can unfold all the data in OSN. DOS, DDOS, Flooding (Unicorn, etc) are functionality based attacks that eventually lead to denial of services along with data unavailability and leakage.

Users' location is a key privacy measure. Location of a user in social network discloses many things to a data analyst. This information causes severe threats for a user after disclosing the location.

2) Database: Database Theft and SQL Injection are very common threats to databases. Leakage/theft of data reveals complete social network data and cause misuse of the whole database. SQL Injection is a hacking technique to access the database without any legitimate authentication. A successful SQL Injection may cause leakage of the whole database.

3) Internet / Internet Service Providers: Insecure authentication, communication interception are known vulnerabilities in the usage of online application. Doxing, Evil Twin, Phishing & Pharming, Browser Sniffing, Network Sniffing, Baiting, Sybil attack, Hactivism, XSS and CSRF are some examples of such vulnerabilities. Companies providing Internet services to social network users have access to users' data traveling through their channels. Mechanisms exist to protect data during transportation. If data in communication is not encrypted, it is visible to everyone on the network. Doxing is the phenomenon in which an unknown person can publish victims information without his/her consent. No one of us is hereby ethically allowed others personal / privacy information on the Internet. Wireless network attacks exist in which a Wi-Fi access point can illegally represents itself as a legitimate one. Phishing refers to the attack in which an adversary attempts to reveal to the user's sensitive information by masquerading as a trustworthy entity. Pharming explains a cyber-attack intended to divert or redirect Internet traffic to another site.

Browser Sniffing is an act of detecting a browser of the victim whereas Network Sniffing / Packet Sniffing is a technique to analyze network packets for solving network problems. These techniques can be used for capturing user data. In a Sybil attack, an insecure hijacked computer claims multiple identities. Baiting are the threats which are carried out using the greedy attitude of the user. The user is tempted/seduced

for some charm. Hacktivism is the subversive use of computers and computer networks to promote a political agenda. Cross-site scripting and cross-site [1] request forgery are such Internet-based attacks in which scripts are executed remotely on user/victims' machines.

B. Social Network Website / App

In this category, threats related to Social Network Website / App are covered. These threats mostly cover the issues related to the technical aspects of computer / Smartphone communication architecture [58]. Phishing, Vishing (Voice Phishing), Smishing, Application Vulnerabilities, Social Data Generation, Data Mining, SocioNet Graphs lie in this category. Similar to Phishing in infrastructure, at the website or application level, it leaks user data to others. In Vishing(Voice Phishing), audio calls using voice changers are used to get private info using Internet / social media application. Smishing is another type of Phishing, in which SMS services are used and users are fooled for financial or some other benefits. Like other computer software, most of the social network applications are vulnerable to exploitations. Social media applications for computers and/or Smart Phones also have some hidden vulnerabilities that are used for privacy leakage as described by Samsung Smart TV case [6], [8]. In Social Data Generation, users records of identities, usages, friends' lists, likes, and comments are centrally stored. These collections of social media items at a central place provide too much knowledge about users' personal information. By using some data extraction methods provided by every social application, Social data is generated for information extraction purposes.

Data Mining tools and techniques provide a wide range of pattern finding methods on social databases. SocioNet Graphs, another automatic method to draw social graphs to find links among network actors can reveal user privacy[92]. User privacy settings/measures, published contents can be extracted from social media accounts [93] which itself is the worst threat. Similar, Top-K strong pattern finding approaches are described in [94].

C. User(S)

This dimension of threats is related to the user, her behavior and usage of OSN [48]. It is very important for a user, "How an individual takes care of his/her data and is responding to the different situations". Identity Theft, Profile access control, Cyber Stalking / Cyber Bullying, Installed Applications, Surveillance Perspective, Social Privacy Perspective, Mutual-friend, Anonymity Risks, Script Generated Requests are common examples of threats which falls in this category. User identity is sole property to get legitimate access to his/her social space. Identity theft is the stealing of someone identity and to pretend as someone else. Profile Access Control is crucial whereas Web technologies provide seamless, open sharing of data on social networks using the concept of Open Web and Cloud Computing. Online harassment of users is known as Cyber Stalking or Cyber Bullying. This is only possible if mostly private data of victim is available to others. All the applications a user installs on Computer / Smart Phone are not confirmed for vulnerability proof. Applications may have vulnerabilities that may be exploited and used as Trojan horses. Every member in a social network cannot be guaranteed as a friend, he may be acting a surveillance actor [95]. For an individual, social activities of a user are shared on the social network, and to the people in a user's network. His likes and locations open users' privacy to the social network. Mutual-friend based or Friend of a friend scam is very much popular regarding social network privacy [78]. Attribute disclosure causes leakage of privacy information [79]. Location, Address, Educational Institutes, Friends, Likes, and Comments are some of the attributes that identify a user. Their disclosure also causes privacy issues in social networks and leads to threats/attacks. Anonymous data access and profile exploration cause data privacy leakage issues in social networks [96]. The script generated anonymous requests to join a network cause severe threat, and the majority of users accept requests without confirming the source.

D. Miscellaneous

Surveillance Perspective, Cyber Espionage/Cyber Spying, Information War, Cyber Terror, Cyber Crimes, and the social privacy - overall perspective is general cyber threats that affect user privacy [5], [73], [82].

Monitoring others and having eyes on others is made very much easy while using a social network and social surveillance. After establishing a social network, Cyber Espionage starts. Research explains that knowingly or unknowingly, every actor spies on the others. The social network is providing a comprehensive data bank for information warfare, which is available for use either positively or negatively. Cyber terror is based on the appearance of an adversary on the Internet, especially via the social network. The social network, not only affects a single one, but it may harm the whole network of an individual [74], [66]. Cyber Terror and other Cyber-crimes are examples of social network data usage. In larger perspective, social privacy also includes complete information of an area, explaining user's trends, market search, and the community likes and dislikes.

V. Discussion

Use and misuse, both exist simultaneously everywhere. Social Media is providing a platform for finding market flow, making users opinions, setting a trend and political move. With the development and advancement of data mining applications, data analysis, pattern finding, network link establishment, inference development and making an individual's family tree is not a difficult task. Most e-banking, telemarketing, credit card systems and telecommunication services need only a few parameters for user authentication. A person, with malicious-intentions, may follow the individual for some time on the social media, collect data, make references, and infer useful parameters and then finally launch an attack. Criminals need data to plan for their activities. The more data and analysis power they have, the probability of success in their activities increases exponentially. It is obvious, that social media is providing a huge data-bank for this purpose. Identity Theft, ATM Skimming, Spear Phishing are few examples in this regards. An overview of these frauds is given in Table I.

A. Disasters after a Compromised Privacy

The majority of Cyber Frauds are based on privacy leaks. Cyber Frauds are mostly initialized because of privacy leaks.

Well-known International Cyber Frauds list is being maintained by the FBI. These frauds can be categorized in different domains and at different levels.

1) Direct finance / Cash involvement: Financial benefits are the core objectives of criminals. They try their best for financial benefits and utilize different approaches. For example, (a) Advance Fee Schemes, in which the greedy victim gives some money and expects something of greater value in return in terms of financial benefits such as approval of the loan, service contract, business investment, or a gift whereas receives much little or even nothing in return. (b) Bankruptcy Fraud is a white-collar crime that commonly takes place where an individual intentionally submits false or incomplete forms. (c) Corporate Fraud can be defined as any fraud committed against a commercial activity. Fraud affecting that target commercial activity can be from general frauds to sector specific frauds. (d) Funeral Fraud or Prepaid Funeral Scams, where service regulations like prepaid funeral service vary from state to state and provide a chance for deceiving operators to overprice and list themselves as beneficiaries. (e) Insider Trading, the trading of financial commodities by insiders with material where non-public information pertaining to a significance is shared and hence often market-moving developments occur which benefit themselves or others financially. These developments can include undecided mergers and procurements, expected earnings releases, and product line progresses. (f) Market Manipulation Fraud generally referred to as a pump and dump which creates artificial demand pressure for a targeted commodity i.e. security or share in a stock exchange, in general, a low-trading volume issuer (over-the-counter) in the securities market mostly administered and controlled by the fraud committers. (g) Credit Card Fraud is a famous wide-ranging term for fraud and theft committed used by a payment card, such as a credit card or debit card, as a deceitful source of funds in a financial transaction. The reason may be to buy something or to get unlawful funds from an account. The unlawful use of a bank card, or matching number, to deceitfully obtain assets or money is also known as credit card fraud. (h) Financial Institution Frauds, another class of criminal schemes which targets traditional as well as modern retail banks, credit card unions, and other similar federally-insured financial institutions. Such type of schemes involve the compromised customers' accounts or personal identifying information; where stolen account identities belong to any of the financial institution or customers are considered victims. Mortgage fraud is a sub-category of such frauds. For example a lie, based on the social engineering or social information leakage, that influences a bank's decision about whether to approve or disapprove a loan, accept or reject a reduced payoff amount, or agree to a certain defined repayment terms. (i) Nigerian Letter Frauds comprise the threats of impersonation with a type of an advance fee scheme in which a letter is forwarded via courier or e-mailed, from Nigeria and offers the opportunity to the recipient to share some amount out of a heavy amount that the author i.e. a self-proclaimed official of their government, trying to transfer somewhere out of the country illegally. It is also known as Nigerian 419 fraud. (j) Investment and Business Frauds highlight the activities of stakeholders in a dishonest or an illegal manner designed to be beneficial for the establishment or the executing person and manage the escort by insiders. (k) Letter of Credit (L/C) Frauds is such types which are often attempted against financial institutions like banks by providing incorrect information in the documentation to prove that required goods have been shipped whereas in reality no goods or at least inferior goods were shipped. (l) Ransom-ware is a type of malware that infects computers, networks, and servers using encryption to make files unreadable. Afterwards, cyber attackers demand a ransom to return the files.

2) Online activities: Online activities where proper information and social network security is not accounted for, may cause severe disasters [97] (a) Identity theft is another type of authentication fraud occurs when someone assumes others' identity to perform a fraud or a criminal act. (b) Timeshare Scams where criminals hire marketing agents for their benefits and sometimes pays a little as a reward. (c) Another extremely sophisticated kind of malware is GameOver Zeus. This malware is engineered categorically to steal banking and other credentials from the computers. It is broadcasted through e-mails as well as phishing methods. (d) Work-at-Home Scams, just like Timeshare schemes, criminals initially try to gain the trust of job seekers/victims by offering very seductive plans varying from ad posting to email checking, etc.

3) Bank notes / Bonds: (a) Prime Bank Note Fraud. The need of such frauds is commonly to embolden the victim to transfer money to a bank outside his/her country where it is eventually received into an off-shore account in the control of the main artist. Furthermore, this money is used for the perpetrator's personal benefits/expenses or is laundered in an effort to make it disappear. (b) Redemption / Strawman / Bond Fraud. Criminals use such financial documents that appear to be legitimate but are not in reality. (c) Securities and Commodities Fraud is a wide range of illegal activities, all of which involve the deception of investors or the manipulation of financial markets. (d) Social Security Card Fraud is similar to identity theft frauds where criminals use Social Security Card information to launch any exploit. (e) Staged Auto Accident Fraud is fraudulently claiming much more re-reimbursement of a car accident expenses which never met or of low intensity / less expensive. (f) Stock Options Backdating is manipulating stock statistics with respect to the current market situation.

4) Market manipulation: Artificial Share Value Raising, Ponzi and Pyramid Schemes are used for market manipulation. Using telemarketing approaches some other approaches include: (a) Anti-Aging Product Fraud, (b) Foreclosure Fraud, (c) Health Care Fraud, (d) Internet Pharmacy Fraud, (e) Mass Marketing Fraud, (f) Online Auction Fraud, (g) Online Auto Auction Fraud, (h) Telemarketing Fraud.

5) Social engineering: Victimizing users using their social information falls in this category. A broadened list of Social Engineering Scams consists of the following approaches: (a) Scareware, (b) Grandparent Scam, (c) Lottery Scams, (d) Natural Disaster Fraud, (e) Online Dating Scams, (f) Reverse Mortgage Scams, (g) Senior Citizen Fraud, (h) Smishing, (i) Spear Phishing, (j) Sports Memorabilia Fraud, (k) Surrogacy Scam, (l) Swatting, (m) Telephone Denial of Service Fraud, (n) House Stealing, (o) Jury Duty Scam, (p) Online Rental Housing Scheme, (q) Adoption Scams.

6) Online social networks supporting cyber terrorism: The number of terrorist activities is getting higher in which the Internet is the battlefield [8]. In Cyber Terrorism, following few techniques used as war tools are of high impact [10]. Cyber Terror - A computer-based violence or destruction to target. Innocent victims for a Political or social change. Cyber Stalking People harassment using social media. Social media-based attempts are key elements in collecting information about victims and bullying them by using social data [98]. Cyber Bullying Children harassment using social media. Social media-based attempts are key elements in bullying anyone by using anonymous social IDs. Similarly, Ransomware is also the other dimension of cybersecurity issues [76].

B. Privacy Guidelines

After a comprehensive study of OSN threats, considering measures taken in social networking sites, and using lessons learnt from existing privacy attacks, this survey presents privacy guidelines that each user must consider.

The prime objective of OSNs is content sharing, however, before sharing something it is necessary to have a look at content and only public data should be published for the public. A large number of scams based on social engineering data has been reported and offer very enticing and seductive plans for attraction. It is again very important to verify the authenticity of offers offered on OSNs or Online application.

Surveillance and contact are two contradictory phenomena, users must remain vigilant for privacy parameters. Internet / Application service providers only have an interest in their business and financial benefits. Always keep in mind the reasons and effects of recent privacy leaks. Privacy risks has a very low impact on the service providers as compared to the user. Live with limited financial information shared on social media and never share Credit Card / Debit Card information on Social Media. Hackers need Social information for their financial benefits. In addition, de-activate stolen Financial Cards and get renewed ones immediately.

Leakage of sibling's information and other blood relatives may cause severe disaster so avoid disclosing such information. Blood relatives' information is manipulated by criminals for financial benefits. Posting of vacation and traveling plan on social media is not advised and visiting suspicious pages and links is strongly discouraged. Never respond to any request/offers until/unless the source is confirmed. After all, a user has sole responsibility for his/her data privacy so take care of data as well as privacy and remain alert and vigilant about strangers.

C. Open Research Problems

Here we provide the OSN privacy issues/threats that are still an open challenge for researchers.

- Malware - Malware is small software applications used to collect user information/data. Antivirus programs can detect malware using their signatures; however, in the case of Malvertising, a systematic solution is not available, user's attentive response is very much necessary.
- XSS: Cross Site Scripting vulnerability has been in practice for a long time by the attackers. Encryption was introduced to protect web data, however, in the case of Key Compromises and "Man in The Middle Attack" encryption becomes useless.
- SQL Injection: SQL injection is a technique [99] used to collect data in database connected application. This type of vulnerability can further be made multifarious using DOS, DDO, and DNS hijacking attacks. Encryption facilitates in protecting from SQL Injection, however, in case of encryption key compromise, no solution is yet available.
- Symmetric Key Compromises: Asymmetric key encryption mechanism (PKI infrastructure) has been introduced. Digital signatures are very much in practice to implement Information Security practices. In the case of Digital Signatures Theft or Public Key loss, renewal of these is suggested, however, during the period of compromise, no mechanism still found.
- Two Factors Authentication: Two-factor authentication is in practice in order to manage and maintain security and provides mechanism against Identity Loss. Risks increases if the second source of authentication is already compromised. Further measures are required to handle such types of vulnerabilities.
- Solutions Required for Multidimensional Threats: FoaF Scams, Interaction vs Surveillance, Independent Group of Friends, and Security Keys (Text Files) in the case of password loss are still very important, critical and useful dimensions for research.

D. Known Solutions and Problem Areas

Along with maturity in security parameters, some useful developments also appeared in social network applications. The antivirus industry has been quite a mature database to handle issues of viruses, malware, Spywares and Spams having already detected signatures. Different Malware and their detection approaches are described in [100].

Cross-site scripting and Cross-site request forgery attacks are web-based attacks. Careful and vigilant browsing help in the prevention of such attacks and encrypted data communication also provides a security layer. Another problem of key compromises in symmetric encryption keys has been solved using Asymmetric encryption keys (Public Key Infrastructure).

Users' social data remains public in most of the cases which cause identity theft. Multi-factor and multi-channel authentication was introduced to provide protection against identity theft [101].

E. Solutions Still Awaited

Though different solutions have been developed to provide security and privacy measures in social network applications, however, following grey areas and their solutions are still awaited. Advertising is very common in social networking applications which is being used for malicious intentions.

Malvertising is an approach in which hackers publish links in social network applications for different products where a

victim gets compromised after clicking the given link. Two distinct keys, Private and Public, are used in Public Key Infrastructure. it becomes the worst scenario when a Private key is compromised and the victim is totally unaware of it unless some criminal activity is detected. Friend of a Friend Scams (FoaF Scams) and Independent Group of Friends are popular vulnerabilities in social networks.

How a user can detect surveillance and differentiate it form interaction. In the case of password loss, Security Keys (Text Files) have been introduced by different web application providers. what if security keys themselves got lost.

VI. Conclusions

In this paper, security and privacy issues related to social network and social engineering are discussed. Latest risks and vulnerabilities are highlighted. A taxonomy is developed by organizing threats into different categories. From a user point of view, few considerations like lessons learned are provided as privacy guidelines to take care of user privacy. Social Networking is open to all as it has been materialized long ago because it is Social. Users must respond responsibly and use social media only for public matters (reduce and control private information/data sharing).

Availability, customization, and enforcement of a set of well-defined privacy and security policies for social media are very crucial. Using a strong password, changing passwords frequently, information disclosure threats and measures, using antivirus, and certified software can secure social networks and limit the possibility of attacks and vulnerabilities. Anything once shared on social media is away from user control. As compared to the privacy risks affecting a user, no one else is at stake.

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TABLE I. FRAUDS WITH THEIR CATEGORIZATION AFTER A COMPROMISED PRIVACY

Social Engineering	**Bank Notes / Bonds**	**Direct Finance / Cash Involvement**	**Grey Areas**
Scareware	Prime Bank Note Fraud	Advance Fee Schemes	Adoption Scams
Grandparent Scam	Redemption/Strawman / Bond Fraud	Bankruptcy Fraud	ATM Skimming
Lottery Scams	Securities and Commodities Fraud	Corporate Fraud	Identity Theft
Natural Disaster Fraud	Social Security Card Fraud	Credit Card Fraud	Phishing
Online Dating Scams	Staged Auto Accident Fraud	Financial Institution Fraud	
Reverse Mortgage Scams	Stock Options Backdating	Funeral Fraud —	Online Activities
Senior Citizen Fraud	Telemarketing	Insider Trading	Pump-and-Dump Stock Scheme
Smishing	Anti-Aging Product Fraud	Prepaid Funeral Scams	Timeshare Schemes
Spear Phishing	Foreclosure Fraud	Insurance Fraud	Gameover Malware
Sports Memorabilia Fraud	Health Care Fraud	Investment Fraud	Work-at-Home Scams
Surrogacy Scam	The Internet Pharmacy Fraud	Letter of Credit Fraud	Artificial Share Value Raising Market Manipulation
Swatting	Mass Marketing Fraud	Mortgage Fraud	Ponzi Schemes
Telephone Denial of Service Fraud	Online Auction Fraud	Nigerian Letter or “419” Fraud	Pyramid Schemes
House Stealing	Online Auto Auction Fraud		
Jury Duty Scam	Telemarketing Fraud		
Online Rental Housing Scheme			

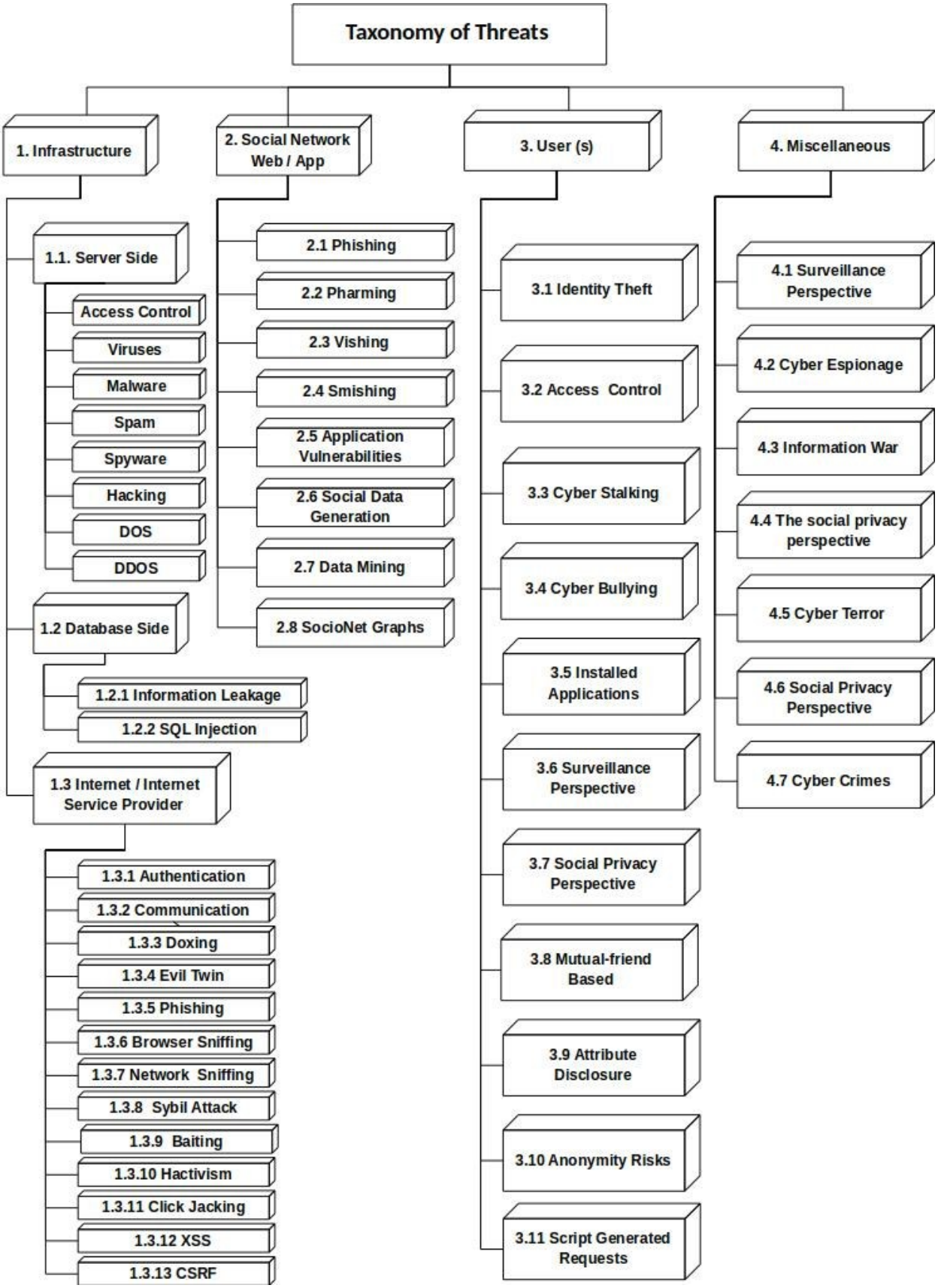

Fig. 1. Taxonomy of Threats to Online Social Networks

New Criteria for Comparing Global Stochastic Derivative-Free Optimization Algorithms

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***Abstract*—For many situations, the function that best models a situation or data set can have a derivative that may be difficult or impossible to find, leading to difficulties in obtaining information about the optimal values of the function. Thus, numerical methods for finding these important values without the direct involvement of the derivative have been developed, making the representation and interpretation of the results for these algorithms of importance to the researchers using them. This is the motivation to use and compare between derivative-free optimization (DFO) algorithms. The comparison methods developed in this paper were tested using three global solvers: Genetic Algorithm (GA), Particle Swarm Optimization (PSO), and Simulated Annealing (SA) on a set of 26 n-dimensional test problems of varying convexity, continuity, differentiability, separability, and modality. Each solver was run 100 times per problem at 2, 20, 50 and 100 dimensions. The formulation for each algorithm used comes from the MATLAB Optimization Toolbox, unedited or revised. New criteria for comparing DFO solver performance are introduced in terms defined as Speed, Accuracy, and Efficiency, taken at different levels of precision and dimensionality. The numerical results for these benchmark problems are analyzed using these methods.**

Keywords*—Derivative-free optimization; algorithm comparison; test problem benchmarking.

I. Introduction

When deciding which algorithm is most appropriate to use on a given problem, it is crucial to have a detailed and encompassing description of how the algorithm will perform when applied in different contexts. Equally important is that the description of the algorithm is comprised of measures which can be universally applied to any other algorithm and thus, used as an objective basis for comparison between many algorithms. This paper aims to define a set of characteristics that begin to form this basis through providing information on the speed at which a solver completes a problem, the efficiency at which resources are used to determine solutions, and the accuracy/success rate of a solver on a problem. The testing each of these measures provided both intuitive and non-intuitive results.

Prior to this study, most of the benchmarking and performance information for GA, PSO and SA was either very specific to a limited number of circumstances or was only mentioned in passing while discussing another topic. The goal of this study is to expand upon what is known about the capabilities of these solvers, while using them as a means of applying and testing the comparison methods that are proposed in Section 3. The parameters we will be mainly focused on comparing across are dimension and problem type. These are two areas that substantially influence solver performance, which makes knowing the details on how exactly these areas impact performance important in the improvement of these solvers as well as the development of solvers with similar characteristics that are capable of circumventing the discovered weaknesses to these parameters.

This paper is meant as a preliminary study into what characteristics are necessary to describe DFO algorithm performance. Further study into what these characteristics may be is encouraged and could lead to a set of attributes beyond those initially proposed within this paper. We seek to provide useful measures of comparison specifically for derivative-free approaches to optimization because there is a wide variance in how derivative-free optimization is performed, which makes having a fair premise for comparison desirable.

A. Background

In [1], performance and data profiles are introduced and used on a set of three solvers applied to three problem types: smooth, piecewise smooth and noisy. Performance profiles are given as a measure for determining the relative differences in the proportion of problems solvable by one solver compared to another. Data profiles provide an independent comparison of what proportion of a problem set can be solved within a given budget of simplex gradients. Performance and data profiles derive their utility from their ability to consolidate the results of many test problems and the subsequent solver performance data from a common comparison criteria. Most often this criteria will be the computational budget: the number of function evaluations or the CPU time required to run the iterations. The information provided in a data profile will inform as to which solver is best when comparing across the problem's computational expense, while performance profiles provide information that relates to a fixed budget relative comparison. Currently, the most prominent method for comparing derivative-free optimization algorithms is the use of performance and data profiles, as discussed in [2].

In [2], 22 solvers were tested on over 500 problems in which the results were compared using performance and data profiles. The overarching conclusion of their comparison was that the solvers TOMLAB/MULTIMIN, TOMLAB/GLCCLUSTER, MCS, and TOMLAB/LGO performed the best on average for the given problems. These are packages that come from the TOMLAB software, which is a very powerful modeling environment software used for solving optimization problems; TOMLAB is implemented in MATLAB. These

implementations take advantage of clustering techniques, scatter search algorithms, as well as Lipschitzian optimization techniques such as branch-and-bound and DIRECT algorithm.

In [3], the authors give measures for comparing algorithms by way of defining characteristics in terms of raw performance data. These comparative measures are used in addition to the criteria used in [1] on performance and data profiles. A background, as well as the motivations and complications with benchmarking optimization algorithms are given and thereafter used to provide an example of a method for how researchers ought to approach the benchmarking process. Important considerations for future papers on the comparison of solvers are raised such as having a large enough set of problems that are also of a wide enough variety. The information presented in the data profiles is used in conjunction with other methods of analysis to properly illustrate a fair and unambiguous representation of solver performance, which demonstrates a better-informed process to follow when comparing algorithms.

In [4] "No Free Lunch Theorems for Optimization", David H. Wolpert and William G. Macready propose the No Free Lunch (NFL) Theorems, which state that no single algorithm can be the overall best algorithm for all problem types. This implies that an optimization algorithm that is strong on one set of problems will show weaknesses in other types. The ideas of what it means for an algorithm to be well suited for a problem are also presented. This theorem is central to the further development of future algorithms, which can be enhanced and informed by the information provided by a strong set of comparison criteria.

II. Algorithms Tested

For the experiments, testing consisted of three derivative-free solvers that were global and stochastic in nature: Genetic Algorithm (GA), Particle Swarm Optimization (PSO), and Simulated Annealing (SA).

A. Genetic Algorithm

Genetic Algorithm operates based on the ideas of evolution, where the sample points in the search space are seen as members of a population. As the number of iterations increases, the reported values by each of the individuals improves towards the optimal solution, analogous to the survival of the "most fit" individual in a population. GA also incorporates techniques inspired by other biological processes such as cross-over and mutation via binary encoding and permutation encoding in order to diversify the values obtained in the hope of finding numbers with higher fitness values [5], [6]. The general form of this process happens in the following manner:

Genetic Algorithm

1. Values are taken from the search space.

2. Fitness values calculated.

3. Lower fitness values go through crossover and mutation and higher fitness values are stored for future mutation/crossover with other individuals of comparably high fitness values.

4. Repeat until convergence.

B. Particle Swarm Optimization

Particle Swarm Optimization utilizes the idea of swarm intelligence to use a set of search particles randomly dispersed around the search space to improve the best iterate value by comparison between each particle's value. PSO is built on vector equations of each particle's position and velocity in the space, and these parameters are adjusted and updated after each iteration, relative to the best value found during that iteration. The values obtained by each individual particle in the space are considered their personal best for the given run, and the best value found by any particle during any iteration is defined as the global best value [7], [8], [9]. All particles update their position (x) and velocity (v) equations according to the global best. These equations are given by:

$$x^i_{k+1} = x^i_k + v^i_{k+1}$$

$$v^i_{k+1} = wv^i_k + c_1 r_1(p^i_k - x^i_k) + c_2 r_2(p^g_k - x^i_k)$$

Where:

x^i_k = the current position of particle i at iteration k.

x^i_{k+1} = the position of an individual particle for the subsequent iteration

v^i_k = the current velocity of particle i at iteration k.

v^i_{k+1} = the velocity of the particle for the subsequent iteration

p^i_k = the personal best value achieved by particle i

p^g_k = the best value achieved for any particle so far

c_1, c_2 = cognitive and social parameters

r_1, r_2 = random numbers between 0 and 1

w = the inertia weight

All of these components come together in ways that distinguish PSO in its approach to solving global optimization problems. The term in the velocity equation wv^i_k is the inertia term, which gives weighting to the current values obtained by the particle to resist extreme changes based on each individual random value obtained during the search. The term $c_1 r_1(p^i_k - x^i_k)$ is the cognitive term, which is the personal supervising term that weights the data of the individual particles prior to inter-particle comparison as well as prior to updating the iterate value to ensure improvement. The term given by $c_2 r_2(p^g_k - x^i_k)$ is the social term, which permits the influence of data returned by each particle to change the behavior of the swarm. This process of updating vector equations based on values gathered from the search space continues while other particles in the swarm continue traversing the space pseudorandomly to discover new points in an effort to avoid trapping with local minima. This continues until convergence on the solution, with parameter functionality further described in [10]. The general form of implementation for PSO typically runs in the following way:

Particle Swarm Optimization

1. Define and Initialize variables and particles.

2. Particles take random values from the space.

3. If value x improves PBest, set PBest = x, otherwise continue searching.

4. Update velocity and position vectors for the PBest of each particle relative to GBest.

5. Repeat until convergence of GBest to minimum.

C. Simulated Annealing

Simulated Annealing is an adaptation of a Monte Carlo Method [11] for solving global optimization problems, accomplished by simulating a thermodynamic system. In SA, points are randomly sampled from the search space according to the probability of a point improving the state of the system where points are seen as sample states of the thermodynamic system. A cooling schedule associated with the "temperatures" in the space tends to zero as the algorithm converges to a solution: lower values obtained progress this schedule as they represent lower energy states in the system [12], [13]. This is a probabilistic solver that runs according to the following general form:

Simulated Annealing

1. Select a data point randomly from the search space.

2. Calculate the the cost difference between current and prospective point.

3. If $cost_{new} < cost_{current}$, accept new.

4. If $cost_{new} > cost_{current}$, accept, but modify the probability of selecting future points that do not improve $cost_{current}$.

5. Repeat until Temperature (T) $\rightarrow$ 0 (convergence).

III. Attributes and Criteria for Comparison

In order to provide an objective basis for comparing global optimization algorithms, a delineation must be made between the aspects of the solution method that are innate to the solver's metaheuristic process and the aspects that are general to all solvers. The aspects of the solution methods that are similar between the solvers will come through in the analysis of performance trends via comparing algorithms relatively, as well as tracking the changes in performance over problem type and dimensionality.

An example of what it means to investigate the qualities of algorithms can be seen by examining the differences between PSO and SA. Note that although both PSO and SA are global stochastic solvers, each is different in how it approaches a given problem. The main differences between PSO and SA are in their search methods. PSO is a population-based solver that uses multiple particles in communication with one another to collectively find the solution, whereas SA is a single point search algorithm that uses a probability function to assess points ability to improve a thermodynamic system. The idea being investigated here is whether there are descriptions of solver behavior that allow for comparing different solvers through the ways in which the functionalities of the algorithms are fundamentally the same. Section 3 discusses attributes that begin the formation of a basis for comparing these different approaches to DFO. Some algorithms may prove to be stronger in a particular attribute than others, and this difference stands to differentiate between where each algorithm can be effectively used in application, which would agree with [4]. In trying to determine the effectiveness of these new metrics for ascertaining key information on solver performance, the best indication that a metric is well defined and capable of providing useful information is if both a clear relationship is demonstrated and the relationship is consistent with the observations in the raw data. The metrics below are defined in terms of the resulting data obtained from running the solver on any problem.

Speed

Speed is defined by the following ratio:

$$\text{Speed} = \frac{\text{Average Number of Function Evaluations}}{\text{Average CPU time}}. \quad (1)$$

This ratio indicates the relative expense of an evaluation of the algorithm, expressed as related to CPU time, which is a known indicator of the computational expense of the algorithm [3]. Speed can be used to see how factors such as dimensionality and problem type affect the computational expense of a run of the solver, which has implications about how well an algorithm would scale with dimension.

Accuracy

The Accuracy of a solver is defined as the proportion of runs in which the global minimum was successfully found within a tolerance of ϵ. Here, ϵ represents the difference between the best value found by the solver and the optimal value, and was taken at ϵ = 10^{0}, ϵ = 10^{-2}, ϵ = 10^{-5} and ϵ = 10^{-10}. The success rate graphs represent the average proportion of successful runs for each solver on the total number of problems within a given group of problems. Accuracy will be represented by the variable A_ϵ, meaning the accuracy of a solver at the corresponding tolerance level ϵ.

Efficiency

The Efficiency of a solver is designed to give an indication as to how well a solver is performing across areas of Speed, Accuracy, ability to achieve the global minimum in as few runs as possible, and also the ability to obtain the minimum in a low number of runs on average:

$$\text{Efficiency} = M * \chi * S * A_\epsilon \quad (2)$$

Where :

$$M = \frac{\log_{10}(M^*)}{\log_{10}(M_i)}$$

$$\chi = \frac{\log_{10}(\chi^*)}{\log_{10}(\chi_i)}$$

$$S = \frac{\log_{10}(S_i)}{\log_{10}(S^*)}$$

Defined by:

A_ϵ = the accuracy value for the given solver within ϵ.

M_i = the mean number of evaluations taken by solver i for a given problem.

M^* = the lowest mean number of evaluations taken by any solver for a given problem.

χ_i = the mean lowest number of evaluations by solver i for a given problem.

χ^* =the absolute lowest number of evaluations by any solver for a given problem.

S_i = the speed of solver i for a given problem.

S^* =the speed of the fastest solver for a given problem.

For each of these three areas (M, χ, S) in which a algorithm performs the best, it will have a corresponding value of 1 and therefore will not receive any loss in Efficiency. However, the Efficiency values of the subsequently lower performing algorithms will be dampened by the M, χ, and S factors. Thus if a solver is the top performer, its Efficiency will equal its Accuracy. Efficiency is only calculated using runs in which the global minimum was obtained. If a solver had runs in which the global minimum was not obtained, the Efficiency of that solver was set to 0 for those runs.

Difficulty

When any solver is applied to a problem requiring a high accuracy, we expect difficulties for the solver resulting in more CPU time or more function evaluations. The chance of failure is very high for achieving a highly accurate solution. Difficulty is given by the following:

$$\text{Difficulty} = -ln(1 - \text{failure}) = -ln(\text{success}) \qquad (3)$$

This is the metric used in [14], which was used to measure the performance of PSO.

These metrics provide more detail in the information obtained on solver performance, as to highlight more specific areas in which a given algorithm may see strength or issue. Contrasting this with the information obtained through the use of performance and data profiles, the purpose of the results discussed in this paper are not intended to give a direct overview of the solver's capabilities with respect to some constraint such as computational budget, but rather to look into more detailed questions within the context of the whole performance. This is done by defining sub-categories of performance (Accuracy, Speed and Efficiency) which can assess the effort required on the part of the solver to obtain the optimal value. This then gives rise to a more generalized form of obtaining and representing the different levels of performance and success within these shared areas of aptitude.

IV. Numerical Experiments

All numerical experiments for GA, PSO, and SA were run on an iMac, version 10.13.6, Processor 4.2 GHz Intel Core i7, 64 GB 2400 MHz DDR4 memory. The implementation of each algorithm used the default settings in the MATLAB Optimization Toolbox [15], with the stopping criteria for all being within the tolerance $\epsilon = 10^{-10}$. The budget here is 10^6 function evaluations.

Limitations

In an effort to maintain the reproducibility of this experiment, no implementations of GA, PSO or SA from outside of MATLAB were used. There are many adaptations of GA [16], many hybrids of PSO with other optimization techniques [17], [18], [19], and popular variations of SA [20] seen across different fields such as engineering and machine learning with these algorithms producing competitive results. These solvers and their advantages are not discussed within the scope of this paper. Given that this paper seeks to discuss manners of comparison and benchmarking along with the representations for these metrics, the algorithms used need only function as examples to demonstrate a comparison process.

Problem Types

In order to see the differences in performance across a variety of problem types as well as a range of dimensions, it is important to classify the set of test problems into 4 groups of the following types:

G1: non-convex, continuous, differentiable, non-separable, multimodal.

G2: convex, non-differentiable, continuous, separable, unimodal.

G3: non-convex, non-differentiable, non-separable, multimodal.

G4: All of the listed types.

Groups

Problems within G1, G2, G3 and G4

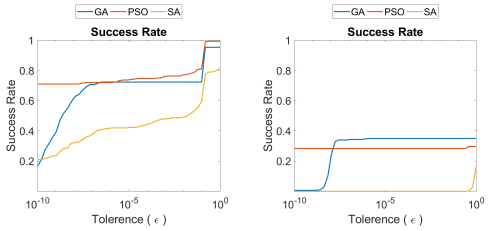
G1	**G4**
alpinen2fcn	ackleyfcn
periodicfcn	alpinen1fcn
shubert4fcn	alpinen2fcn
	periodicfcn
G2	rosenbrockfcn
powellsumfcn	salomonfcn
schwefel220fcn	shubertfcn
schwefel223fcn	shubert3fcn
	shubert4fcn
	xinsheyangn3fcn
G3	powellsumfcn
schwefelfcn	schwefel220fcn
xinsheyangn2fcn	schwefel221fcn
xinsheyangn4fcn	schwefel222fcn
	schwefel223fcn
	exponentialfcn
	sumsquaresfcn
	xinsheyangn1fcn
	xinsheyangn2fcn
	xinsheyangn4fcn
	griewankfcn
	quarticfcn
	rastriginfcn
	styblinskitankfcn
	zakharovfcn

V. Results

A. Accuracy

In Fig. 1, all solvers display competitive performance at 2 dimensions. Yet as the dimension increased, each solver's performance decreased at different rates with GA having

decreased the least among all solvers leaving GA capable of solving at least one of the problems in G1 within 10^{-7} for all dimensions. GA showed a gradual reduction in success from 20 to 100 dimensions, coming through as the algorithm which was most robust to changes in dimensionality for G1. For the problems in G1, PSO observed the most dramatic change in performance, demonstrating higher sensitivity to changes in dimensionality. SA dropped to near zero at just 20 dimensions, showing SA to be the least competitive on this set.

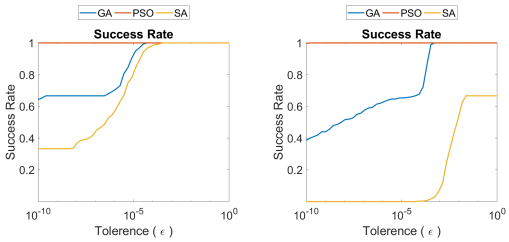


(a) Dimension = 2 (b) Dimension = 20

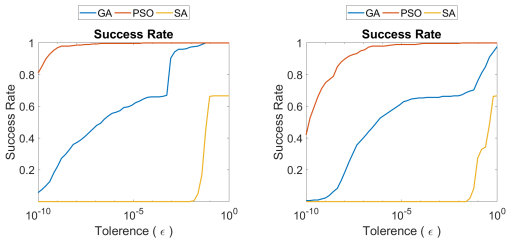
(c) Dimension = 50 (d) Dimension = 100

Fig. 1. Accuracy for G1

All solvers performed significantly better on G2 than on G1. This indicates that the differences in problem type had a sizable impact on performance, despite the problems of G2 being non-differentiable. Fig. 2 shows that the problems of G2 remained 100% solvable by all solvers at 2 dimensions for $\epsilon > 10^{-3}$. All solvers showed a decrease in success rate as ϵ decreased. In comparing the performance of PSO on G2 to G1, unlike in G1, there is less sensitivity to dimensionality within G2. Thus it seems likely that the characteristics of the problems in G2 are more favorable for PSO's heuristic. GA once again shows a resistance to a loss in success from 2 to 100 dimensions, yet does not outperform PSO on this set due to the amount by which PSO's performance increased from G1. SA is once again approaching a success rate of zero for most observed values of ϵ below about 10^{-2} for dimensions greater than 20, which makes SA a less competitive choice on a problem set similar to G2.



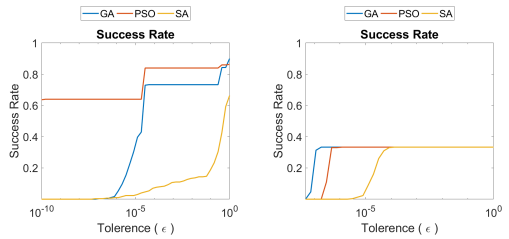
(a) Dimension = 2 (b) Dimension = 20



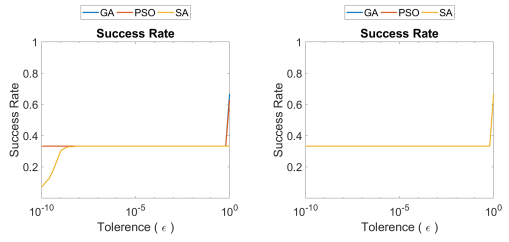
(c) Dimension = 50 (d) Dimension = 100

Fig. 2. Accuracy for G2

The results of G3 were quite unintuitive. The behavior of the solvers was not strongly correlated with dimension in the same way as in G1 and in G2. Behavior for this group was much more problem dependent, where in Fig. 3 going from 2 to 100 dimensions, each solver is shown to have had one problem they remained capable of solving, with an *increase* in the success rate of each algorithm as dimensionality increased and as ϵ decreased. Note that each algorithm achieved a success rate of 33% for G3, meaning that each solver failed two of the three problems every time, but succeeded on the remaining problem each time. There is no clear explanation for this behavior, making it a point of interest for further investigation.



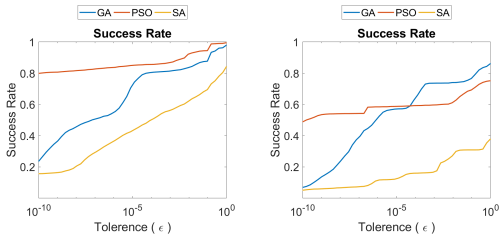
(a) Dimension = 2 (b) Dimension = 20



(c) Dimension = 50 (d) Dimension = 100

Fig. 3. Accuracy for G3

Fig. 4 shows a decreasing trend in solver ability to obtain the global minimum for small ϵ as well as for high dimensionality. We take G4 as a strong indication as to how solver performance will average out across a variety of problems of different or mixed type, showing the expected trends that would arise from general use of any of these algorithms. Algorithms which tend to have a shallow slope display a high level of consistency across the levels of ϵ. Notice that although PSO maintains this consistency, its Accuracy drops as dimension increases. Solvers like SA that cannot resist a loss in Accuracy for higher dimensions and higher ϵ will see their success rate go to zero much quicker than other algorithms. GA has a sharper slope than PSO or SA, but does not translate as far down the graph when dimension increases. This trend in the amount to which success rates decrease shows GA to be the most robust for ϵ level (10^{-4}, 10^{-4}, 10^{-2}) for dimensions 20, 50 and 100 respectively. PSO, however, is able to achieve the highest success rate for small ϵ as opposed to GA or SA.



(a) Dimension = 2 (b) Dimension = 20

(c) Dimension = 50 (d) Dimension = 100

Fig. 4. Accuracy for G4

Accuracy proved to be a very effective tool in analyzing the performance of the solvers in terms of their reliability for finding the global minimum on problems of varying type and difficulty. There was a large spread in performance across the groups, suggesting that Accuracy is able to identify changes in the solution capability of the solvers on these types of problems. Accuracy also showed that problem type greatly affected solver ability to produce highly accurate values for the minimum.

B. Speed

The trends observed in Speed for each group yielded similar results, including G3. When looking to Fig. 5, the graph of Speed for G4, a clear ordering from the fastest to slowest solver emerges and remains consistent from 2 to 100 dimensions. However, the response to the increase in dimension was different for each solver:

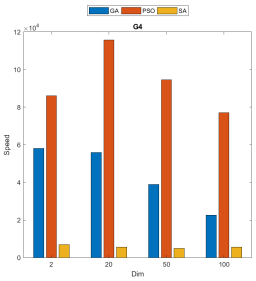
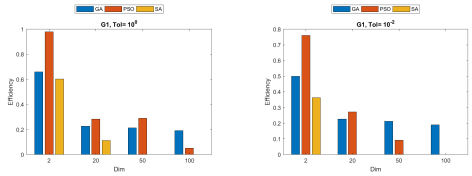


Fig. 5. Average Speed for G4

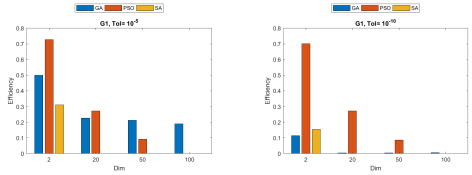
GA was virtually unaffected by dimensionality until after 20 dimensions where there is then a steady decrease going to 100 dimensions. For SA, there seemed to be little effect on Speed as a result of increasing dimension, however SA was consistently the slowest of the three. PSO's behavior between 2 and 50 dimensions was unanticipated. There was an increase in Speed from 2 to 20 dimensions, prior to an eventual and steady decline moving towards 100 dimensions. One possible account for this is a difference in the rate of change in evaluations taken by the solver compared to CPU time needed to take those evaluations of the function at different dimensions, meaning that the rate at which the number of evaluations grew with dimension outpaced the increase in CPU time taken until after 20 dimensions. The differences in the relationships of each solver's Speed value to the dimensionality of the problem shows how the strengths of the approach by each algorithm affect the use computational resources. Knowing how each algorithm uses these resources is important for assessing the utility of an algorithm for a task, especially one requiring performance that is both computationally inexpensive and fast.

C. Efficiency

The Efficiencies for G1 show that the characteristics of the problems posed a significant challenge for the solvers, despite the fact that the problems in G1 were differentiable. This indicates a strong relationship between problem type and general difficulty, further supported in Fig. 10 and also in the comparison of Fig. 6 and Fig. 7. GA is shown to be not as efficient as PSO when ϵ decreases, but GA remains the most efficient for higher dimensional problems. This further supports the claim that GA has a resistance to loss in Accuracy for higher dimensional problems. Note that solvers that had no runs in which the global was obtained within ϵ have Efficiencies of 0. Overall, it seems that the performance for all solvers dropped significantly with dimension, which corroborates the results from Accuracy.



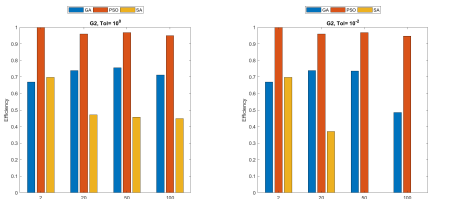
(a) $\epsilon = 10^{0}$ (b) $\epsilon = 10^{-2}$



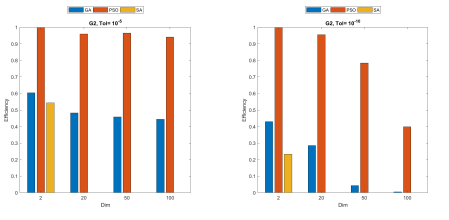
(c) $\epsilon = 10^{-5}$ (d) $\epsilon = 10^{-10}$

Fig. 6. Efficiencies for G1

As opposed to G1, the characteristics of the problems in G2 were significantly easier for the solvers, despite being non-differentiable problems. Each algorithm performed noticeably better across dimension and tolerance. PSO is the most sensitive to the problem characteristics, as its performance across different groups displays a large variance. This sensitivity, however, has shown to benefit PSO, as PSO had the highest Efficiency value at every tolerance and dimension. GA was robust to changes in tolerance across each group, while SA was most affected by tolerance, as one may notice that the Efficiency value for SA dropped to zero for 50 and 100 dimensions after an increase in the tolerance from $\epsilon = 10^{0}$ to $\epsilon = 10^{-2}$. As the Accuracy plots for G3 suggested, there were some problems for which the solvers saw a slight increase in performance as dimension increased. Although not as extreme as in G3, subtle increases in Efficiency for GA can be seen across each dimension at $\epsilon = 10^{0}$ to $\epsilon = 10^{-2}$ in G2.



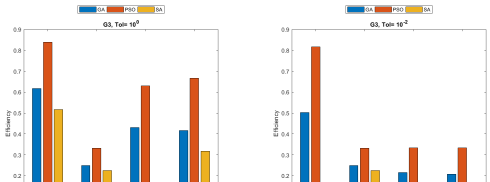
(a) $\epsilon = 10^{0}$ (b) $\epsilon = 10^{-2}$



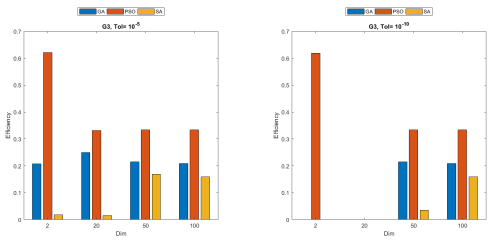
(c) $\epsilon = 10^{-5}$ (d) $\epsilon = 10^{-10}$

Fig. 7. Efficiencies for G2

G3 exhibited trends in performance that did not follow the implication of the other groups. The Efficiency values for G3 did *not* consistently decrease with dimension. Instead, Fig. 8 shows a drop in performance from 2 to 20 dimensions, which becomes more and more magnified as ϵ decreases, followed by an increase in performance from 20 to 100 dimensions. Further investigation into this group shows that after 25 dimensions, the decreasing trend in performance turns around and the solvers show a resurgence in Efficiency for higher dimensions. This implies that there are qualities of these problems that elicit a difference in solver approach from within the algorithms themselves. The results for Efficiency of G3 also corroborate what was observed in the results for the Accuracy of G3. However, unlike in the Accuracy for G3, we do not see the same equilibrium phenomena where each solver approaches solving one out of three problems each time, but rather we see a score of zero for all solvers at 20 dimensions for $\epsilon = 10^{-10}$. This means that there were no values for either M_i, χ_i, or S_i for any solver at this level, and thus at 20 dimensions the Efficiency values for each solver were assigned a value of 0. The counter-intuitive behavior of the solvers on the problems within G3 will be the subject of further research, as understanding why this happens can more broadly and completely describe solver characteristics.



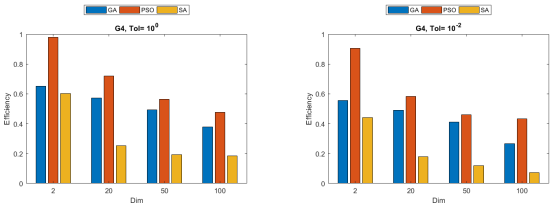
(a) $\epsilon = 10^{0}$ (b) $\epsilon = 10^{-2}$



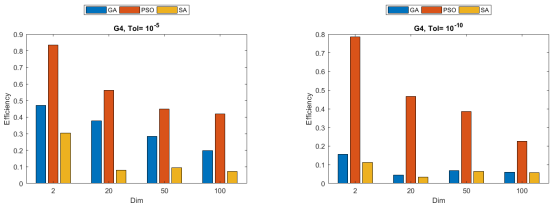
(c) $\epsilon = 10^{-5}$ (d) $\epsilon = 10^{-10}$

Fig. 8. Efficiencies for G3

Just as we examined the Accuracy plots for G4 to gain insight into the average solution capability of each algorithm, we now look to Efficiency values for G4 shown in Fig. 9 to get an indication as to how well the successful attempts at finding the optimal were completed. PSO shows the strongest resistance to loss in Efficiency on solving problems in G4 at low dimensions, while the decreasing trend in performance as dimension increases shows a sharper decline as tolerance increases. GA, however, displays a rather consistent decreasing trend with a shallow change between dimensions. In terms of Efficiency, PSO surmounts GA and SA for all dimensions and tolerances in the long run. Thus, PSO is likely a good choice for when the problem set is mixed.

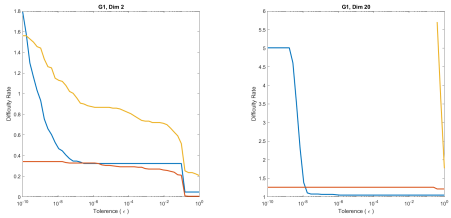


(a) $\epsilon = 10^{0}$ (b) $\epsilon = 10^{-2}$

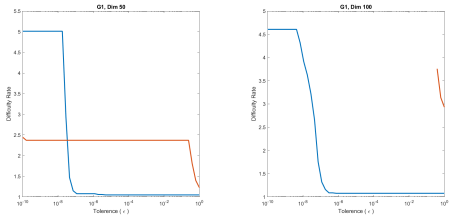


(c) $\epsilon = 10^{-5}$ (d) $\epsilon = 10^{-10}$

Fig. 9. Efficiencies for G4



(a) Dimension = 2 (b) Dimension = 20



(c) Dimension = 50 (d) Dimension = 100

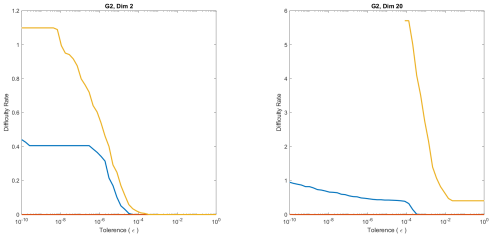
Fig. 10. Difficulties for G1

Efficiency proved to be able to effectively measure the quality of algorithm performance across each parameter we sought to measure. The formulations for the factors of M, χ, and S give proper weighting to each solver's level of ability and balanced for factors that Accuracy alone could not. The consolidation of the information regarding the magnitudes of the best values obtained by a solver into Efficiency makes a solver's Efficiency capable of giving weight to the relative sizes and differences these values in a way that the values themselves do not convey alone, making Efficiency a valuable tool for starting to look into trends within a solvers own performance across dimension and tolerance.

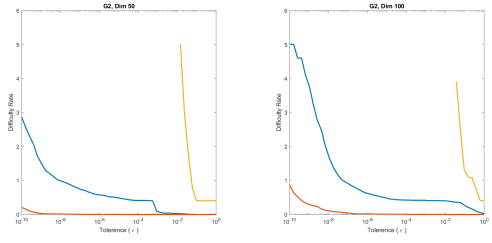
D. Difficulty

The Difficulty values for G1 displayed in Fig. 10 corroborate the comparison of the Efficiency values seen in G1 and G2, showing that the problems in G1 posed a greater challenge to the solvers than did the problems of G2. This further substantiates the idea that it is likely that attributes outside of differentiability must also be considered in determining which solver to choose for a problem set. As it pertains to dimensionality, GA manages the change in dimensions the best, being roughly consistent in its Difficulty rating. PSO's Difficulty rapidly increases from 50 to 100 dimensions, showing yet again a sensitivity to dimension.

The results shown in Fig. 11 also agree with the comparison of the Efficiency values for G1 and G2, but the Difficulty values for G2 give more information about relative solver performance. PSO remains the best solver in keeping the lowest difficulty for all dimensions. This indicates that although there is a demonstrated sensitivity for PSO to dimension, it seems quite possible based on the G2 difficulty graphs that given the optimal set of problem characteristics, PSO's increase in performance for these types of problems outweigh the effects of dimensionality. GA does no share the same strength in awareness to problem type, as its performance is similar to G1. SA shows some improvement on G2, yet still struggled as dimension increased.



(a) Dimension = 2 (b) Dimension = 20

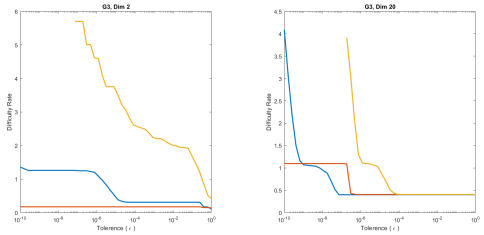


(c) Dimension = 50 (d) Dimension = 100

Fig. 11. Difficulties for G2

The Difficulty values for G3 shown in Fig. 12 display a

similarly odd trend to what we saw in Fig. 3 and Fig. 8. We see that Difficulty *decreases* for higher dimensions after a spike at 20 dimensions. The reasons for this remain unclear. The entire set was run multiple times and similar results were seen. It is possible that problems of the same type as G3 would elicit similar behavior from the solvers that is not only atypical of the general trends we have observed, but also does not fit into what we saw or expected for PSO's sensitivity to dimension or GA's consistency in performance. The tendency to move towards an equilibrium value is seen in the Difficulty of G3 as was seen in the Accuracy for G3.

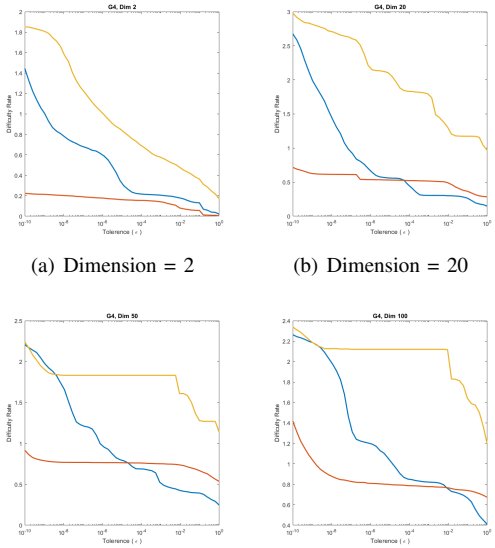


(a) Dimension = 2 (b) Dimension = 20

(c) Dimension = 50 (d) Dimension = 100

Fig. 12. Difficulties for G3

The Difficulty values for G4 seen in Fig. 13 show that, overall, the trends in Difficulty for solvers maintained a consistent placement of the solvers relative to one another. Note also that the expected trend that Difficulty increases with dimension. Seeing that all solvers did well on G4 gives an indication that certain problems may have attributes that worked well with each algorithms heuristic, which improved their Difficulty rating overall. SA's improvement on these types of problems could mean that the particular attributes of the problems in G1 and G2 were especially challenging for SA compared to other problem types.



(a) Dimension = 2 (b) Dimension = 20

(c) Dimension = 50 (d) Dimension = 100

Fig. 13. Difficulties for G4

Difficulty supports the proposed methods for identifying pertinent trends in performance that can be objectively measured between solvers. Difficulty also allows for more depth in searching for explanations of trends seen in Efficiency, Accuracy and Speed that may not be superficially obvious, such as the relatively small differences between GA and SA in Difficulty seen in Fig. 13, despite the larger differences in Accuracy and Efficiency. This indicates that the work required for GA to obtain optimal values led more often to success than that of SA. This demonstrates even further that looking within the details of benchmarking methods is crucial to fully describing solver performance, and that the decision between applying one solver versus another can be more informed by the knowledge of what exactly goes into solving each problem for each solver.

VI. Conclusions

It was seen in the analysis of each solver's performance across G1, G2, G3 and G4 that problem type and dimension play a key role in determining which algorithm will be most successful in a given context. There were a variety of outcomes among the solvers as to how often the global minimum could be obtained, as well as how precise that value could be. In looking across each group, with the exception of G3, it is shown that the data for each characteristic corroborated the trends displayed in one another. Describing algorithmic behavior in terms of Accuracy, Efficiency and Speed demonstrates the strengths and weaknesses of these algorithms in a way that formalizes performance into a comprehensive qualitative and quantitative description.

One of the main strengths that GA exhibited on the groups was a resistance to changes in dimension, making GA a strong choice for higher dimensional problems. Also, GA maintained a competitive Accuracy for large ϵ, outperforming PSO in some cases, as seen in Fig. 1 and Fig. 4. A weakness observed for GA was a sensitivity to tolerance, meaning that as ϵ

decreased, GA observed significant drops in its attribute values. Note also that GA had a rather large average number of evaluations, which in turn reduced GA's Speed.

PSO was, for the most part, the strongest algorithm on each group. PSO showed not only an impressive resistance to loss in Accuracy across tolerance, but also consistently had the highest Speed value of all solvers. PSO's consistency across tolerance makes it a strong choice for problems requiring knowledge of the minimum to within small ϵ. PSO would also be the best choice for low dimensional problems, as PSO enjoys a high success rate for most problems below 20 dimensions. PSO's performance was only significantly affected during changes in dimension. For although the minimum found by PSO is highly accurate and precise, PSO still saw a large drop in Accuracy as dimension increased, seen specifically in Fig. 1, were PSO translated down the graph for each observed dimension. It must be said, however, that this weakness for PSO that was also seen in Fig. 2 that PSO's sensitivity to dimension had very little, if any, negative effects on PSO's performance. This suggests that PSO has a greater sensitivity to problem type than to dimension, and PSO is more problem conscious than the other solvers, something that both helped and hurt PSO's performance during these experiments.

The performance seen for SA was the least competitive of the three solvers. SA demonstrated an extreme sensitivity to dimension, dropping in Accuracy as much as from about 80% to less than 20% for G1 going from 2 to 20 dimensions in Fig. 1. SA also had the lowest Speed for all solvers, which was on average less than about 15% the Speed of PSO and even less than about 20% that of GA, as seen in Fig. 5. Potential strengths for SA may lie in the further analysis of G3, as this is the only area in which SA observed competitive performance. SA also never observed a difficulty below 1 outside of G3, indicating that even the performance seen on G1, G2 and G4 was a struggle. This indicates that problem type has perhaps the biggest effect on SA.

The characteristics of Speed, Accuracy and Efficiency provide useful information about solver performance and give a clear description of solver capabilities within these areas. Certain problems produced solver behavior that defied intuition and expected trends in the data, which shows the current descriptions of solver behavior to be, although useful, incomplete. This emphasizes the need for further research into more criteria which can help describe such phenomena as seen in G3.

VII. Closing Remarks

These experiments were an attempt to begin the formalization of solver performance comparison metrics into a concise and usable format. A formalized set of criteria will hopefully establish a medium for communication between researchers where coherence and consistency in representation of performance will be established. Further testing and study of these criteria is encouraged so that the definitions may improve and new criteria may emerge that will be universally beneficial. The characteristics proposed in this paper were defined using stochastic, global algorithms. Results regarding deterministic solvers and/or local solvers are not observed in this paper and remain a topic for future research. Future research endeavors may also include seeing the effects of parallelizing these algorithms for use on a GPU so that more problems can be run at even higher dimensions, as well as more solvers, as to increase the variety of algorithms considered, including deterministic and local solvers. Looking further into G3 is also a topic of importance as it may lead to progress in determining the cause for the observed behavior, possibly leading also into establishing more characteristics which can help broaden the description of algorithmic trends.

Acknowledgment

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Test Problems

All the test functions [21] were sorted by the following characteristics:

- S = separable
- S' = not separable
- D = differentiable
- D' = non-differentiable
- C = convex
- C' = non-convex
- U = unimodal
- M = multimodal
- c = continuous
- c' = not continuous
- n = dimension

*xinsheyangn3fcn minimum occurs for m = 5 and β = 15

Function	Characteristics	Range	Optimal	Formulation
ackleyfcn	C′ c D S′ M	[-32,32]	0	$-a \cdot exp(-b\sqrt{\frac{1}{n}\sum_{i=1}^{n} x_i^2}) - exp(\frac{1}{n}\sum_{i=1}^{n} cos(cx_i)) + a + exp(1)$
alpinen1fcn	" "	[0,10]	0	$\sum_{i=1}^{n} \lvert x_i sin(x_i) + 0.1x_i \rvert$
alpinen2fcn	" "	[0,10]	2.808^n	$\prod_{i=1}^{n} \sqrt{x_i} sin(x_i)$
periodicfcn	" "	[-10,10]	0.9	$1 + \sum_{i=1}^{n} sin^2(x_i) - 0.1exp(\sum_{i=1}^{n} x_i^2)$
rosenbrockfcn	" "	[-5,10]	0	$\sum_{i=1}^{n} [b(x_{i+1} - x_i^2)^2 + (a - x_i)^2]$
salomonfcn	" "	[-100,100]	0	$1\text{-}cos(2\pi\sqrt{\sum_{i=1}^{D} x_i^2}) + 0.1\sqrt{\sum_{i=1}^{D} x_i^2}$
shubertfcn	" "	[-10,10]	-186.73	$\prod_{i=1}^{n}\left(\sum_{j=1}^{5} cos((j+1)x_i + j)\right)$
shubert3fcn	" "	[-10,10]	-29.673	$\sum_{i=1}^{n}\sum_{j=1}^{5} jsin((j+1)x_i + j)$
shubert4fcn	" "	[-10,10]	-25.7408	$\sum_{i=1}^{n}\sum_{j=1}^{5} jcos((j+1)x_i + j)$
xinsheyangn3fcn	" "	$[-2\pi, 2\pi]$	-1 *	$exp(-\sum_{i=1}^{n}(x_i/\beta)^{2m})$ - $2exp(-\sum_{i=1}^{n} x_i^2) \prod_{i=1}^{n} cos^2(x_i)$
powellsumfcn	C c D′ S U	[-1,1]	0	$\sum_{i=1}^{n} \lvert x_i \rvert^{i+1}$
schwefel220fcn	" "	[-100,100]	0	$\sum_{i=1}^{n} \lvert x_i \rvert$
schwefel221fcn	" "	[-100,100]	0	$\max_{i=1,\ldots,n} \lvert x_i \rvert$
schwefel222fcn	" "	[-100,100]	0	$\sum_{i=1}^{n} \lvert x_i \rvert + \prod_{i=1}^{n} \lvert x_i \rvert$
schwefel223fcn	" "	[-10,10]	0	$\sum_{i=1}^{n} x_i^{10}$
exponentialfcn	C c D S′ U	[-1,1]	0	$-exp(-0.5\sum_{i=1}^{n} x_i^2)$
sumsquaresfcn	C c D S U	[-10,10]	0	$\sum_{i=1}^{n} ix_i^2$
xinsheyangn1fcn	C′ c′ D′ S′ M	[-5,5]	0	$\sum_{i=1}^{n} \epsilon_i \lvert x_i \rvert^i$
xinsheyangn2fcn	C′ c D′ S′ M	$[-2\pi, 2\pi]$	0	$\sum_{i=1}^{n} (\lvert x_i \rvert)\ exp(-\sum_{i=1}^{n} \text{sin(x\_i^2)})$
xinsheyangn4fcn	C′ c D′ S′ M	[-10,10]	-1	$\left(\sum_{i=1}^{n} sin^2(x_i) - exp(-\sum_{i=1}^{n} x_i^2)\right) exp(-\sum_{i=1}^{n} sin^2\sqrt{\lvert x_i \rvert})$
griewankfcn	C′ c D S U	[-600,600]	0	$1 + \sum_{i=1}^{n} \frac{x_i^2}{4000} - \prod_{i=1}^{n} cos(\frac{x_i}{\sqrt{i}})$
quarticfcn	C′c D S M	[-1.28,1.28]	0	$\sum_{i=1}^{n} ix_i^4 + \text{random}[0, 1)$
rastriginfcn	C′ c D S M	[-5.12,5.12]	0	$10n + \sum_{i=1}^{n} (x_i^2 - 10cos(2\pi x_i))$
styblinskitankfcn	C′ c D S M	[-5,5]	$-39.1659n$	$\frac{1}{2}\sum_{i=1}^{n} (x_i^4 - 16x_i^2 + 5x_i)$
zakharovfcn	C c D S M	[-5,10]	0	$\sum_{i=1}^{n} x_i^2 + (\sum_{i=1}^{n} 0.5ix_i)^2 + (\sum_{i=1}^{n} 0.5ix_i)^4$
schwefelfcn	C' c D' S' M	[-500,500]	0	$418.9829\text{d} - \sum_{i=1}^{n} x_i sin(\sqrt{\lvert x_i \rvert})$

A Survey on Location Privacy-Preserving Mechanisms in Mobile Crowdsourcing

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***Abstract*—Mobile Crowdsourcing (MCS) surfaced as a new affluent method for data collection and processing as a result of the boom of sensor-rich mobile devices popularity. MCS still has room for improvement, particularly in protecting workers' private information such as location. Therefore, the installation of privacy-preserving mechanisms that insulate sensitive information and prevent attackers from obtaining information is a necessity. In this paper, we discuss location privacy threats and analyze some recently proposed mechanisms that targeted location privacy in mobile crowdsourcing. Finally, we compare and evaluate these mechanisms according to specific criteria that we define in this paper.**

Keywords*—Mobile crowdsourcing; privacy; security; location privacy-preserving

I. Introduction

Crowdsourcing has been an evolutionary concept since 2006 when it was first introduced by Jeff Howe [1]. It can be viewed as an open call for problem-solving through the engagement of large groups of people. Those groups could be chosen according to specific criteria, for example, their job title, medical history, or their salary. Crowdsourcing enabled adequate and effective data collection solution [2].

With technology revolutions, smartphones are equipped with various kinds of sensors and thus became more powerful. This led to emerging smartphones into crowdsourcing and elevated participating level in performing various tasks to a new era. Specifically, in 2012 is when the concept of Mobile crowdsourcing (MCS) was introduced [3]. This concept is based on joining computers and humans to make crowdsourcing even more efficient with data uniquely generated and collected from multiple smartphones [4].

As a result of the growth of sensors and mobile devices popularity, Mobile Crowdsourcing (MCS) applications surfaced as a new affluent method for data collection. In MCS systems, exposure to security and privacy threats exists due to the human involvement and mobility characteristic. MCS systems still have room for improvement, particularly in protecting task and workers' private information such as identities and locations [5]. Therefore, a lot of researches proposed privacy-preserving mechanisms that insulate sensitive information and prevent attackers from obtaining access to private information.

With the growth of the MCS models, there have been other platforms extended from the MCS concept like Spatial Crowdsourcing (SC). The main characteristic of SC is that workers must be present in a specific location to accomplish the spatial tasks [6]. In this paper, we use both terms exchangeably.

This paper focuses on the issue of preserving the privacy of crowdworkers to increase their participation in fulfilling various tasks. The main goal of this paper is to review the state-of-the-art research on privacy-preserving techniques in spatial crowdsourcing.

This paper is organized as follows: Section II introduces the MCS model and its main entities. Section III presents location-based privacy threats. Section IV reviews recent approaches that have been proposed as solutions for location privacy-preserving. Section V discusses and compares the previously reviewed solutions. Section VI concludes the paper.

II. The MCS Model

MCS systems compose of four main entities: an end user or requester, a service provider (SP), crowdworkers, and a task. These entities interact with each other in real time. These four main components and the workflow among them are illustrated in Fig. 1. In the following paragraphs, we describe these four entities and the interaction among them.

- *End user (Requester)*
  An end user is the owner of the task that he/she wishes to be performed by certain people, and for that, he/she announces his/her tasks through a service provider and receives the response through the service provider.
- *Service Provider (SP)*
  SP acts as a trusted mediator between requesters and workers. It provides the platform for crowdsourcing services in which a SP receives a request from a requester and assigns it to the proper workers according to specific criteria, for example, workers' locations, task requirements, etc. An SP is responsible for incentivizing workers to participate in performing tasks through rewording system or any other mechanism that guarantees the willingness of workers to complete a task with correct responses.
- *Crowdworkers*
  Crowdworkers are the participants who perform requesters' tasks by providing the SP with responses to the corresponding published tasks. As a reward, workers sometimes get paid for successful participations.

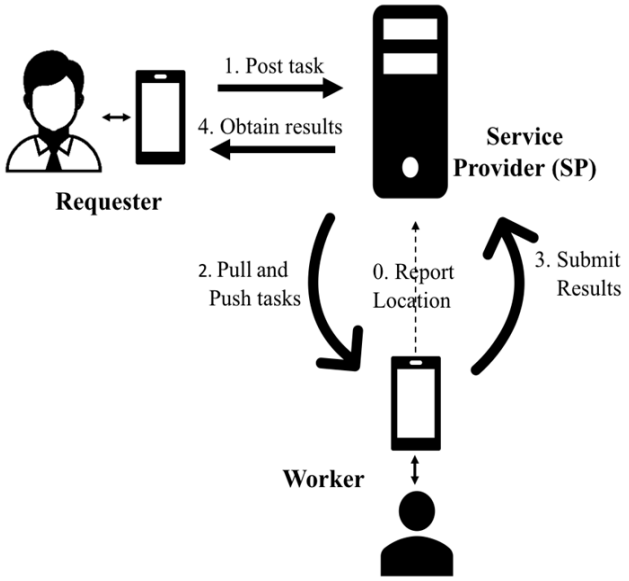

Fig. 1. The MCS Model.

- *Task*
  Task is the job posted by a requester to be accomplished by crowdworkers. This task may contain information about the requesters and their locations. Generally, task assignment has two modes. The first mode is called server-assigned tasks (SAT) and also known as push mode; it is when a task is assigned by a SP to workers. The second mode is called worker-selected tasks (WST) and also known as pull mode. In this mode, workers get to choose what task to perform.

III. Location-based Privacy Threats

There are three issues that are related to MCS: security, privacy, and trust. The MCS threats can be categorized based on these issues as follow:

1) Security threats such as eavesdropping, Sybil attacks, False Data Uploading, are caused by open wireless connections and the distribution and mobility of workers.
2) Privacy threats such as workers data disclosure, end users' personal information leakage and task privacy [7].
3) Trust threats such as worker trust which directly impact data trust.

In this paper, we mainly focus on location privacy-preserving. Before analyzing proposed mechanisms that targeted location privacy, we need to discuss the location-privacy attacks that threaten the crowdworkers locations.

Location-privacy attacks can be divided based on the task assignment mode into pull mode attacks and push mode attacks. The main difference between pull mode and push mode attacks is that in the pull mode, attackers try to identify the area range to find the exact worker's location. But in push mode, the attackers try to identify the worker's location from the location updates.

There are many attacks that can happen on pull mode such as task sampling attack, location homogeneity attack, and map matching attack [6]. The first attack is the task sampling attack in which the attackers link the location of participants to location-based tasks to know the location of a specific worker. The second attack is the location homogeneity attack, where the attacker may link some workers in the same region with the same sensitive attributes and disclose personal information like diseases, hobbies, etc. The last attack is map matching attack, in which attacker eliminates areas from the map such as lakes and rivers where it is impossible for the worker to exist in these areas, this will increases the attacker's chances of finding the worker's exact location.

On the other hand, there are many attacks that can happen on push mode such as task tracking attack, maximum movement boundary attack, and location inference attack. The first attack is the task tracking attack where the attacker tries to learn a pattern from the worker's location updates to disclose other information. The second attack is the maximum movement boundary attack in which the attacker computes maximum movement boundary to specify the worker's location at a specific time. The last attack is the location inference attack where the attacker uses background knowledge and workers' location to disclose workers' privacy.

IV. Location Privacy-Preserving Techniques

There are many research works and proposed techniques that have been conducted to address location privacy concerns. In some systems, workers must send their locations to the service provider to be used later in task assignments. As a result, workers become vulnerable to attacks such as eavesdropping. In contrast, other systems give the worker the authority to choose a task he/she wishes to perform. This means that the worker gets to explore information related to the published tasks. Therefore, proposed privacy-preserving techniques can be categorized into two categories based on the mode of task assignment: SAT and WST. These modes are described in Section II.

In the following paragraphs, we are going to review some recently proposed techniques and organize them based on their mode of task assignment.

A. SAT Mode

Alharthi et al. [8] proposed DCentroid, which is a novel framework for crowd workers location privacy in spatial crowdsourcing (SC). The DCentroid is designed to overcome the issues of the location privacy in SC by utilizing the dummy-based technique. The idea of the proposed mechanism is to hide the actual location of the crowd worker by creating dummy locations instead of the real location then sending these locations to the SC-server. As shown in Fig. 2, the structure of this framework consists of three components which are requester, crowd worker, and SC-server.

The workflow of the DCentroid framework acts as follows: Firstly, the crowd worker creates three dummy locations around the real location by using the Direct Dummy Algorithm. This algorithm generates sixteen directions of the crowd

worker position to realize all possible dummies then it chooses randomly three dummy locations. After that, the algorithm removes the elected point to avoid duplicate selection of that location. This algorithm assumes that the closest point to the crowd worker location must not be further than three units and not less than one unit, in order to ensure the travel distance metrics and to protect the crowd workers privacy. Secondly, the crowd worker issues the dummy locations to the SC-server. Thirdly, the SC-server computes the range of these locations then computes the estimated distance from the crowd worker location to the requester task location by using the Standard Euclidean Distance. Finally, The SC-server issues the task to the closest crowd worker depending on the computed estimated distance.

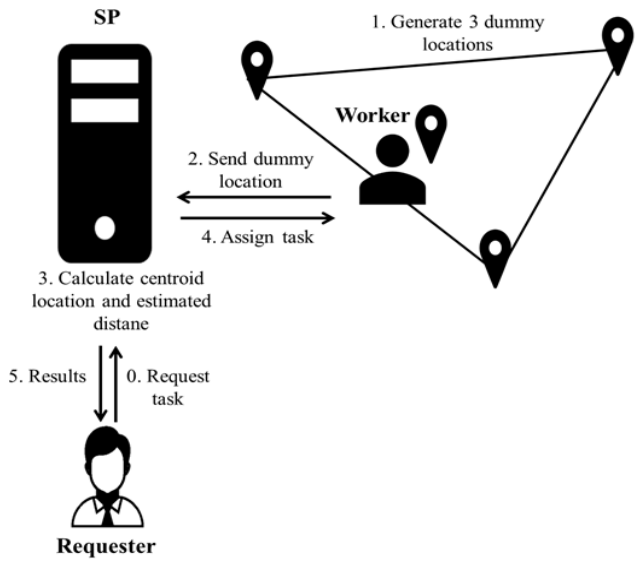

Fig. 2. Dummy-based Location Privacy-preserving Technique [8].

Liu et al. proposed a location privacy framework in [9]. This framework uses homomorphic encryption scheme [10] to protect location privacy and secures index technique to save participants' locations. It contains six phases.

The first phase, Worker Registration, the crowd worker sings up to the registration server SR, encrypts its location using homomorphic encryption scheme and sends the encrypted location to SR. SR will index all workers' locations and store them in secure KD tree. The second phase, Task Submission, the requester submits task's location in the same encrypted way. The third phase, Distance Computation, the computation server SC computes the distance between the worker's location and the task's location without disclosing the real locations (by using homomorphic encryption concept). The fourth phase, Task Assignment, SC assigns the task to the closest worker according to the calculated distance. The fifth phase, Task Notification, SR notifies the worker about the task that he/she needs to perform. Finally in the last phase, in order to enable the worker to know the task location, the requester encrypts the task location with the worker public key and sends it to the worker. The overall framework is shown in Fig. 3. Therefore, This framework protects the location privacy in SC.

Zhu et al. proposed a location privacy scheme that applied the clustering algorithm in [11]. Thus, in this scheme, the distributed spatial clustering algorithm is executed by the workers in proactive and on-demand modes. The proactive mode has more rapid responses in comparison to the on-demand mode because the workers in proactive mode periodically run the clustering algorithm through peer-peer communication links within one hop. However, the proactive mode might result in the escalation of communication overhead. In on-demand mode, the server will broadcast the signal to the workers once it receives the spatial task to initialize the clustering algorithm. Afterward, the workers run the clustering algorithm. Clustering is initiated through every worker choosing a random number between 0 and 1. After that, the cluster head is selected if the random number is less than the threshold value. Therefore, the cluster head will broadcast an advertisement message to non-heads to join a cluster. If a non-head receives 2 or more advertisement messages from different cluster heads, he/she will choose the nearest cluster head and join that cluster. Finally, the head cluster knows all locations of the members in the cluster. After the clustering step, each cluster head sends the location of the virtual cluster center (VCC) which is calculated according to the cluster members' locations. The two-level task assignment algorithm is performed when a requester generates a spatial task as shown in Fig. 4. In the primary level assignment, the server assigns the task to the nearest cluster head to the spatial task's location using VCC location. After that, the secondary level assignment is performed by the chosen cluster head in the primary level assignment. Then, the head assigns the task to the nearest cluster member to the required location by task. Finally, the worker will move to the task's location and perform the task. Therefore, the workers' locations aren't disclosed to the server or to the requester.

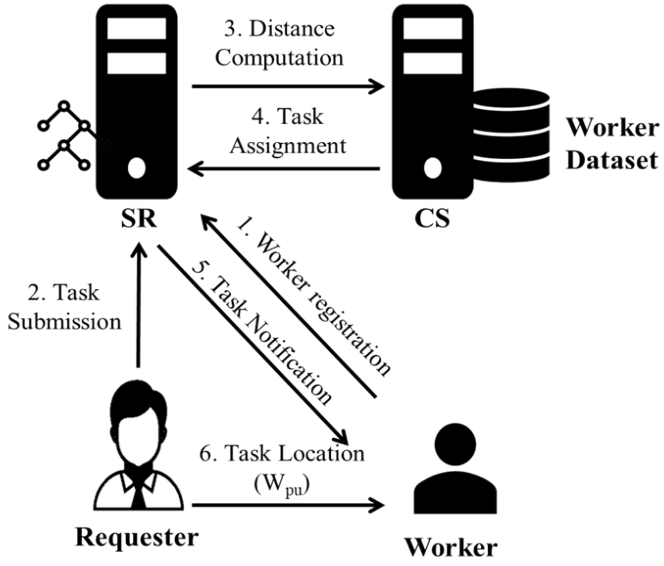

Fig. 3. Homomorphic Encryption Based Framework [9].

B. WST Mode:

Wang et al. [12] focused on two points, the first of which concerns about the auction algorithm while the second is about location privacy-preserving mechanism. Thus, the improved two-stage auction algorithm based on trust degree and privacy sensibility (TATP) is proposed to ensure the dynamics and fairness for the online incentive mechanism. Also, the $k-\varepsilon$ differential is proposed to protect the workers' location information. To encourage workers to participate in tasks and conduct truthfully, the first point is needed. Therefore, TATP is designed to determine winners in real time in contrast to the algorithms that existed previously.

In other words, TATP upgrades the traditional two-stage auction by increasing the truthfulness of auction and removing the injustice that occurred in the traditional two-stage algorithms, which rejected the first batch of workers. The first stage of TATP is the sample collection stage while the second stage is the contest stage that sets the bidding threshold in each transaction dynamically based on the first stage's result. On the other hand, to safeguard workers' location information, the combination between $k-anonymity$ and $\varepsilon-$ differential privacy preserving to produce $k-\varepsilon$ differential privacy-preserving is proposed.

In addition, Gaussian white noise is utilized to $\varepsilon-$ differential privacy-preserving. The $k-anonymity$ is characterized by the following properties: Spatial containment, Spatial resolution, Temporal containment, Temporal resolution, and Location k-anonymity. As a result of applying $k-anonymity$, attackers can't link location information to the correct worker. However, $k-anonymity$ doesn't cover the homogeneity attack dilemma. Therefore, the combination of $k-anonymity$ and $\varepsilon-$differential privacy preserving and the application of Gaussian white noise to $\varepsilon-$differential privacy-preserving is proposed. The relationship between ε and noise is an inverse relationship. So, if ε is smaller, the added noise increases which means more location privacy-preserving is achieved.

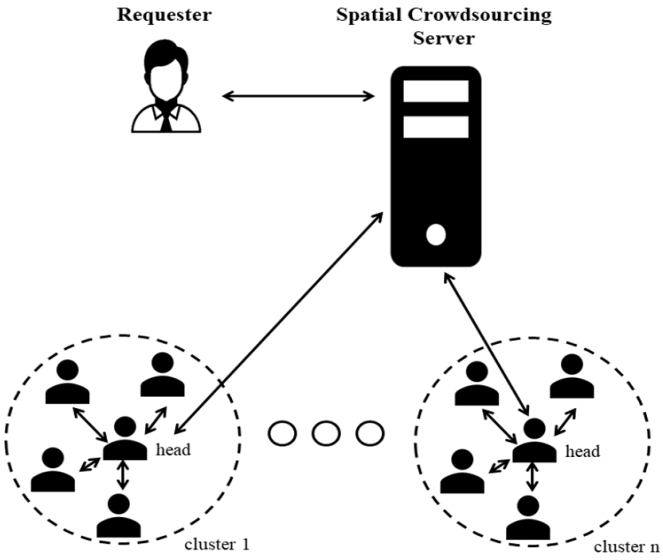

Fig. 4. Cluster-based Location Privacy-preserving Technique [11].

In the end, the experiments are done to assess and evaluate the proposed mechanism efficiency by verifying the effectiveness of TAPT over comparative to other auction algorithms and verifying the effectiveness of $k-\varepsilon-$differential privacy-preserving.

Jia et al. [13] focused on the mechanisms of user motivation to accomplish the tasks in MCS. The most important feature to users in MCS is the location privacy perspective, and for that reason, users may restrain participation and may input incorrect information to protect their privacy. In order to overcome those issues, the mixed incentive mechanism was proposed which consists of privacy protection and blockchain.

The network structure of blockchain is divided into three components which are intelligence crowd sensing networks, confusion mechanism, and blockchain. The crowd sensing network has two kinds of nodes, an ordinary user node which contains user information while the second is a miner node. The main role of the miner node is to produce a new block space. On another hand, the server in the crowd sensing network has two functions to do: issuing task information and get the sensing data from the blockchain. The confusion mechanism is developed to protect the crowd worker information by encoding the node information based on the Confusion Mechanism Encode Algorithm (CMA-E) and the Confusion Mechanism Decode Algorithm (CMA-D). The CMA-E encoded each part of user node information including longitude, latitude, age, gender, hobby, and Occupation.

The last component is the blockchain where the main purpose is to protect the user information from tampering. The structure of blockchain was changed by building the Merkle Tree and Currency Allocation using double-SHA256 hash algorithm. Fig. 5 illustrates the components and transactions of the proposed mechanism, which acts as follows: First, the server publishes a sensing task then the user in the crowd sensing network takes the sensing task. After that the sensing data enters the confusion mechanism as blocks where in each block there are nine user nodes and one mine node. second, the blockchain stores user information and provides the virtual coin to the user as a reward to motivate him to participate then the user can replace it with cash. Finally, the server retrieves the user information from the blockchain.

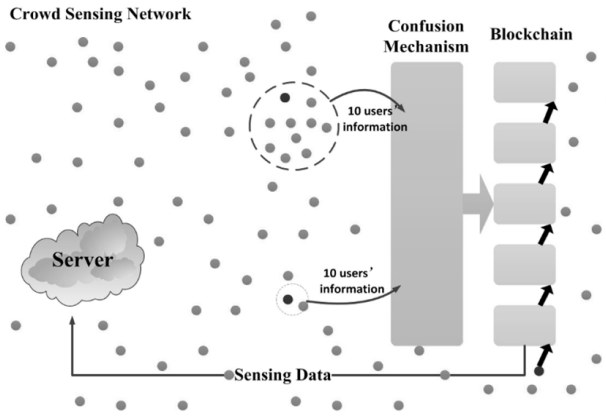

Fig. 5. Blockchain-based Incentive Framework [13].

Alamer et al. presented Location privacy-Aware Task rEcommendation framework (LATE) [14] and designed it to preserve workers' location during task recommendation in spatial crowdsourcing. The LATE framework can accomplish privacy-preserving location-matching between the workers' locations and the spatial task's geocast area by using Lagrange Interpolating Polynomials. Moreover, The LATE framework consists of four components: SC-server, trust management server (TMS), customers, and workers. TMS administers the trust level of workers to assist SC-server in its decision-making about the workers reliability to perform a task.

LATE is composed of four phases: Service Setup, Task Releasing, Task Recommendation, and Task Fulfillment. Firstly, the process initiates with the Service Setup phase, where the CS-server loads all services and establishes the public parameter. It also defines the region's hallmark, which assists in conducting the service geographic region for customers. Furthermore, worker generates a public-private key pair. Afterward, the certificate of the worker is issued from the certificate authority (CA). Moreover, TMS and customer choose a secret key, and calculate their public keys. Then, CA issues a certificate of TMS and customer. Additionally, TMS initializes its service for workers. Secondly, in the Task Releasing phase; when the customer covets using spatial crowdsourcing, the customer creates a task and defines some parameters of the task such as geocast area, expiration time and other attributes (e.g. reporting periods, benefits) illustrated in Cont. To prevent disclosure of geocast area, the customer produces a series of encrypted points of interest. Moreover, it prevents the task's disclosure by encrypting Cont using CA's public key and encrypting the secret key using TMS's public key. Finally, it sends an encrypted task to CS-server. Thirdly, in the Task Recommendation phase; when the worker desires to be involved in activities, the worker interacts with TMS by sending his certificate. The SC-server takes encrypted spatial task and worker's location, then utilizes the matching algorithm to check the worker's location. If the worker is located in the same geocast area of the task, it gets the recommended task. Fourthly, in Task Fulfillment phase; when the worker executes the task and issues the crowdsourcing report, the crowdsourcing report must be protected by the customer's public key.

In the end, the security of LATE is proved by demonstrating that the attacker can't disclose the workers' locations and the spatial task's geocast area since they are encrypted. Also, the efficiency of LATE and practicality in computation and communication overhead are proved.

V. Discussion and Analysis

For the purpose of differentiating between the previously discussed techniques, we conducted a comparison using five main criteria: (1) Location privacy of worker and task, (2) the used technique in implementing each mechanism, (3) the overhead caused by applying every solution on a system, (4) the existence of third party, and (5) task assignment mode. For further illustration, we explain each one as follows:

- Used Technique: There are different methodologies used to hide or preserve the location privacy: Clustering, K-anonymity with $\varepsilon-$differential, Encryption, Blockchain, Dummy based technique, and Homomorphic encryption.
- Location Privacy (Worker | Task): some mechanisms are interested in protecting the worker location or task location, and others are interested in preserving both worker and task's location. From the table we can see that most techniques protect the worker's location, on the other hand, only two technique protect both worker and task's location from disclosure, both of these used encryption-based methodologies.
- Overhead (computational | Communicational): the impact an approach has by applying it to a mobile crowdsourcing system, if it's going to add computational overhead (where there is a lot of value computing required) or communicational overhead (where there is a continuous exchange of messages over the network that might cause high network traffic). We can distinguish three out of the six techniques that encountered overhead. The clustering had both computational and communicational overhead due to the constant calculating of distance on the Proactive Mode, these calculations require more of messages exchange. Similar to clustering, the homomorphic encryption causes both overhead types which come from the frequent update of SKD tree every time the worker changes location which is a time-consuming process when there is a lot of workers. The Blockchain techniques are known for being expensive in computations and communication due to the whole blocks and transactions being transmitted to and validated by all nodes. The Blockchain embeds the consensus algorithm which causes a high computational overhead that would raise with the number of nodes in the network [15] [16].
- Trust Third Party: There is only one solution that will depend on the existence of a trusted third party, which is the encryption technique. The third party usually exists with the assumption that it can be trusted. However, the trust third party does not exist in the real world [17].
- Assign task mode type: As previously mentioned in Section II, assignment mode for a task is either server-assigned task mode (SAT) or worker-selected task mode (WST). From the table, we can observe that half of the techniques are using the SAT mode, and the other half use the WST mode.

Table I presents the summary of the comparison among existing work according the previously specified criteria.

By observing the assessment of the six techniques, we can notice the best technique in terms of the previous criteria for each attack type:

1) In the SAT mode: we think that the Dummy-based technique, with the addition of encrypting the worker's location and the task using homomorphic cryptography, is an optimal solution for preserving location privacy. The dummy technique is a lightweight solution that depends on the idea of calculating centroid that is not the exact location of the worker

TABLE I. SUMMARY OF THE COMPARISON BETWEEN EXISTING WORK.

		Proposed Techniques					
		[11]	[12]	[14]	[13]	[8]	[9]
Used Technique		Clustering	$k-anonymity$ and $\varepsilon-$differential	Encryption	BlockChain	Dummy Based Technique	Homomorphic Encryption
Location Privacy	Worker	✓	✓	✓	✓	✓	✓
	Task			✓			✓
Overhead	Computational	✓	–	–	✓	–	✓
	Communicational	✓	–	–	✓	–	✓
Trusted Third Party		No	No	Yes	No	No	No
Assign task mode		SAT	WST	WST	WST	SAT	SAT

but relatively close to the real data [12]. Adding homomorphic cryptography will add privacy to the task location.

2) In the WST mode: The approach of utilizing both k-Anonymity and $\varepsilon-$differential is a suitable technique to be used for privacy protection in systems that use WST mode. This solution has no overhead impact on the system, and doesn't rely on a trusted third party to implement the mechanism, which makes it worthy of trust.

VI. CONCLUSIONS

Mobile crowdsourcing involves exchanging of sensitive and personal information as a consequence of task sharing and performing. Therefore, protecting both task and worker privacy is essential to encourage workers' participation. In this paper, we discussed attacks related to location disclosure. Moreover, we reviewed recently proposed mechanisms that aim to preserve location privacy, and we compared them and discussed the results of the comparison. Based on the comparison result, we can conclude that for crowdsourcing systems that uses SAT mode, it is better to merge between the Dummy-based technique and homomorphic cryptography to achieve location privacy-preserving. For WST mode, applying k-Anonymity and $\varepsilon-$differential will increase the location privacy-preserving and the trustworthiness of the system. As for the limitation, when deciding the overhead for each approach, we were relaying on the existence of heavy calculations, time consumption, and number communications required. Though we classified overhead into computational and communicational, more clear metrics are needed to compare between different types of overhead.

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Ionospheric Anomalies before the 2015 Deep Earthquake Doublet, M_w 7.5 and M_w 7.6, in Peru

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***Abstract*—Two major earthquakes separated by ∼5 minutes occurred in the same fault in Peru at depths of 606.2 and 620.6 km on November 24, 2015. By using Global Ionospheric Maps (GIMs) from the Center for Orbit Determination in Europe (CODE) and a broadly used statistical method, differential Vertical Total Electron Content (VTEC) maps were derived. Two positive ionospheric anomalies were clearly identified in the differential VTEC maps 2 and 1 day prior to the day of the earthquakes. These anomalies were located inside the earthquakes' preparation regions defined by the Dobrovolsky equation. On the other hand, due to the low-latitude nature of the seismic events, the Equatorial Ionization Anomaly (EIA) shape was also analyzed. A third positive disturbance was revealed between November 20 and 21, 2015. For the aforementioned anomaly and the one on November 22 (2 days before the earthquakes), an enhancement of the VTEC was observe through the considerable modification of the EIA shape into a well-defined double-crest with a trough. By looking into the Dst and Kp indices, the geomagnetic conditions starting on November 20 until the 24 were very quiet; thus, it is considered that the three detected anomalies are precursors to the earthquake doublet. Moreover, it is suggested that the mechanism at work that produced the positive disturbances is the air ionization through the release of radon from the Earth's crust.**

Keywords*—Ionospheric anomalies; earthquakes; total electron content

I. Introduction

Earthquakes can be the cause of major devastations depending on their intensity. Hence in the past years, the detection of seismo-ionospheric signatures has been taking increasingly attention [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17]. There are different methods to detect ionospheric anomalies before a strong earthquake. For instance, [18] and [15] observed ionospheric disturbances prior to earthquakes by looking into the time series of Vertical Total Electron Content (VTEC) derived from GPS stations. On the other hand, [11], [13] and [9], for example, used Global Ionospheric Maps (GIMs) in order to observe better the spatial distributions and dynamics of the anomalies. A third technique, is the observation of the modification of the Equatorial Ionization Anomaly (EIA) for earthquakes that occurred at low-latitudes [1], [2].

The majority of the aforementioned studies [1], [3], [4], [6], [9], [8], [13], [14], [16], that have detected ionospheric disturbance prior to a strong earthquakes, have detected these disturbances for earthquakes that had their origin in the Earth's crust (depth $\leq$ 70 km). Only quite a few studies [19], [12], [15] have looked for seismo-ionospheric signatures in earthquakes that had their origin deeper than the crust. [19] detected a ionospheric anomaly using two-dimensional component analysis one day before the July 7, 2017 earthquake near Papua New Guinea (depth ∼378 km). Once again [12], using the same method, detected for the February 27, 2015 earthquake in Indonesia (depth ∼547 km), a sesimo-ionospheric signature also one day before the incident. [15] detected, by looking into the time series of GPS stations, positive ionospheric anomalies hours before the October 26, 2015 earthquake in Afghanistan (depth ∼200 km).

In this study, global VTEC maps provided by the Center for Orbit Determination in Europe (CODE) were used to observe for ionospheric anomalies preceding the two strong deep earthquakes that happened in Peru on November 24, 2015. Additionally, the latitudinal shape of the EIA will be analyzed due to the low-latitude location of the earthquake doublet.

II. The Earthquake Doublet

Two major earthquakes occurred on November 24, 2015 near the Peru-Brazil border [20], [21]. The first one of magnitude M_w 7.5 happened at 22:45 UT (17:45 local time; LT) and the second one of magnitude M_w 7.6 at 22:50 UT (17:50 LT). The epicenter of the former was located at 10.54°S 70.94°W and of the latter at 10.06°S 71.02°W (Fig. 1). Because of the location of the earthquakes, deep in the Amazon, there were no casualties or infrastructure damage as reported by the media. According to the United States Geological Survey (USGS) the M_w 7.5 and M_w 7.6 earthquakes initiated at depths of 606.2 and 620.6 km, respectively. As indicated by [20] this doublet earthquake, as many that happened in the past in this region, is product of the subduction of the Nazca plate under the South American plate.

Using data from Global Navigation Satellite System (GNSS) receivers from the International GNSS Service (IGS), only a previous study by [15] have detected 12 and 5 days (November 12 and 19, 2015, respectively) before the earthquake doublet positive ionospheric anomalies. [15] detected these anomalies by looking into the VTEC time series of the three nearest GNSS stations to the seismic event. Only two stations, POVE and AREQ, relatively near to the epicenter were able to detect the ionospheric disturbances. The third one, because it was close to the border of the earthquake preparation zone, did not show a clear anomaly.

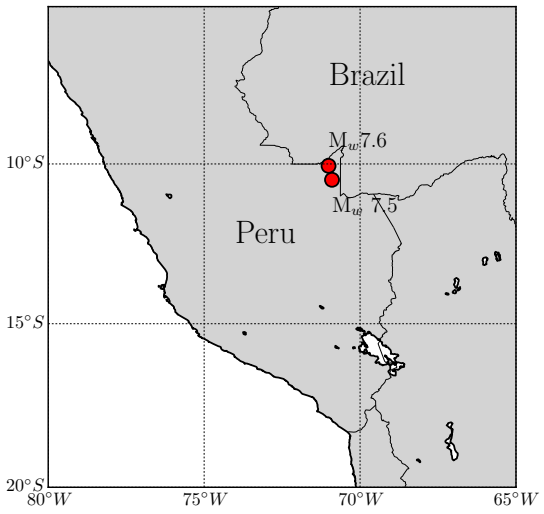

Fig. 1. The two red circles point to the epicenters where the two seismic events occurred on November 24, 2015

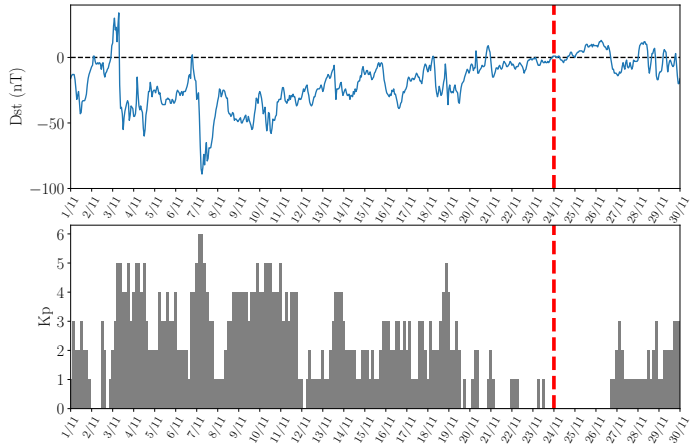

Fig. 2. Dst and Kp indices for November 2015. The vertical dashed red line in both plots indicates the day the two earthquakes happened.

III. Methods

A. Ionospheric Data

GIMs, that are generated on a daily basis through IONEX files [22], were retrieved via ftp (ftp://ftp.aiub.unibe.ch/CODE/). IONEX files in the range between 15 days (November 9, 2015) before and 11 days (December 5, 2015) after the day of the two incidents were downloaded. GIMs are being produced in the recent years every hour, and they consist basically of a 5° x 2.5° geographical grid in longitude and latitude, respectively, of VTEC values. All the GIMs in the selected range of days were stored in 3D cubes, where the three axes of these cubes are latitude, longitude and number of GIMs.

In order to identify the spatial distribution of the ionospheric anomalies, a broadly used statistical method was applied to the VTEC data [18], [4], [6], [9], [11], [14], [23]. To every grid point in the 3D cubes of GIMs, a sliding window was applied to calculate the mean (μ) and the standard deviation (σ). The VTEC for a specific grip point at any given hour on any day within this window is considered to follow a normal distribution. To identify ionospheric disturbances, the confidence level used in this study is higher than the one used by [15]. To detect anomalies with a confidence level of 95%, the upper and lower bounds (UB and LB) were chosen as follows:

$$UB = \mu + 2\sigma, \tag{1}$$

$$LB = \mu - 2\sigma. \tag{2}$$

If a VTEC value at a certain grid point on a particular time falls outside of these bounds, there is an anomaly. The ionospheric anomalies are positive and negative when the VTEC is higher than the UB and lower than the LB, respectively. In this way, differential VTEC (ΔVTEC) maps were generated.

B. Geomagnetic Conditions

To make sure that the detected anomalies are not a product of space weather conditions, the geomagnetic indices, Dst and Kp, for the month of November 2015 were observed. Data for the Dst index were obtained from the World Data Center for Geomagnetism in Kyoto (http://wdc.kugi.kyoto-u.ac.jp/wdc/Sec3.html), and for the Kp index were retrieved from the German Research Center for Geosciences (https://www.gfz-potsdam.de/en/kp-index/). In Fig. 2, it can be seen that between November 3 and 11, the Kp index reached values greater than 4, meaning that there is significant geomagnetic activity. This is further confirmed when data for the Dst index was observed. Since November 3 until November 19, 2015, values of Dst $<$ -20 nT are reached, which points to the existence of weak geomagnetic storms. Between November 20 and 28 the geomagnetic conditions are rather quiet (Dst $>$ -20 nT and Kp $\leq$ 3).

The Earthquakes' Preparation Regions

As indicated by [24], precursors to earthquakes are expected to be observed within a circle defined by the preparation radius:

$$R = 10^{0.43M}[\text{km}], \tag{3}$$

where M is the moment magnitude of an earthquake. For the M_w 7.5 and M_w 7.6 earthquakes, their preparation radius are $\sim$1678 km and $\sim$1853 km, respectively.

IV. Results and Discussion

A. Differential VTEC Maps

After inspection of the ΔVTEC maps, extremely large ionospheric disturbances starting on November 18 at approximately 20:00 UT were observed and they disappeared at around 22:00 UT of the next day (November 19). In Fig. 3 one can see the full extent of these disturbances between 00:00 and 06:00 UT from November 19, 2015. From Fig. 2 it can be seen that towards the end of November 18, the Kp index reaches a

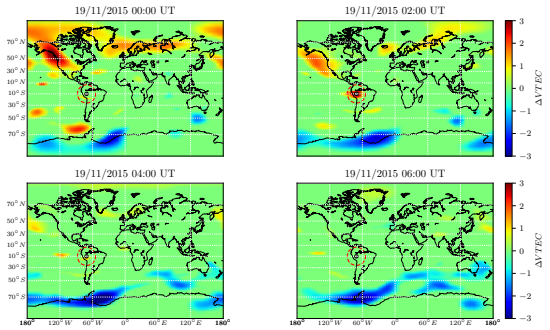

Fig. 3. Global spatial distribution of ΔVTEC for November 19, 2015 between 00:00 - 06:00 UT. The units for the ΔVTEC are TECU, where 1 TECU = 10^{16} electrons/m^2. The grey circles point to the location of the M$_w$ 7.6 earthquake and the dashed red circles define the earthquake preparation zone [24].

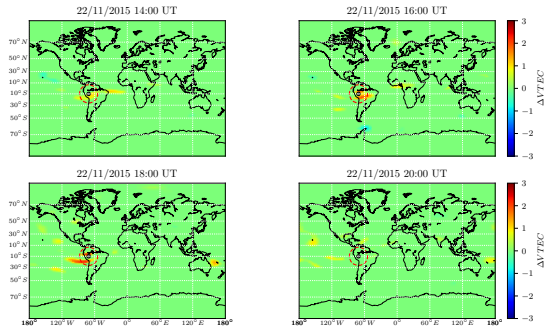

Fig. 4. Global spatial distribution of ΔVTEC for November 22, 2015 between 14:00 - 20:00 UT. The units for the ΔVTEC are TECU, where 1 TECU = 10^{16} electrons/m^2. The grey circles point to the location of the M$_w$ 7.6 earthquake and the dashed red circles define the earthquake preparation zone [24].

value of 5, whereas for these same hours and the early hours of November 19 the Dst index values point to the existence of a small intensity geomagnetic storm (-20 nT $>$ Dst $>$ - 50 nT). In addition, the spatial ionospheric disturbances, positive and negative ones, are clearly of a global scale; hence, it can be considered that these anomalies are very likely originated due to the weak geomagnetic conditions. However, it can not be entirely rule out the possibility that a component of the positive ionospheric anomaly observed right over the epicenters on November 19 at 02:00 UT might be due to the preparation for the seismic events; this due to the pronounced increment of VTEC at this time inside the earthquakes' preparation regions. Due to the size of the presented maps, only the earthquake preparation region ($R \sim$1853 km) for the M_w 7.6 earthquake is shown.

On November 22, 2015 (2 days prior to the two seismic events) a positive ionospheric anomaly appeared at $\sim$14:00 UT, and it remained above the location of both earthquakes until $\sim$20:00 UT, when this already moved to the west (Fig. 4). It is worth noticing that nowhere else in the maps shown in Fig. 4 there are permanent anomalies, only the one detected within the earthquakes preparation zone ($R \sim$1853 km).

In a similar fashion, one day before the earthquake doublet (November 23) another positive anomaly over the location of the epicenters was observed (Fig. 5). This one was present approximately between 08:00 UT and 10:00 UT (03:00-05:00 LT). At 12:00 UT the disturbance started to move westward until it disappeared. As with other studies [25], [5], [9], [13], [11] that observed ionospheric anomalies with their accompanying anomaly in the conjugate geomagnetic region, in Fig. 5 this can not be seen, and this is mainly due the time in which the anomaly was observed (03:00-05:00 LT). At these hours of the day the EIA is not yet above the Peruvian sky.

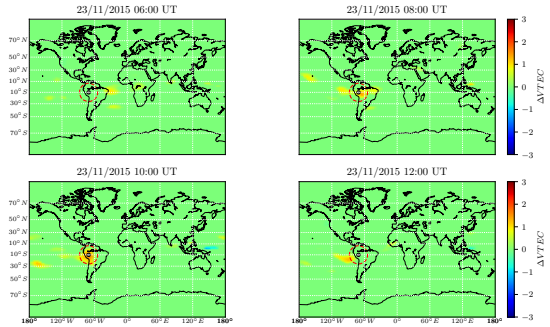

Fig. 5. Global spatial distribution of ΔVTEC for November 23, 2015 between 06:00 - 12:00 UT. The units for the ΔVTEC are TECU, where 1 TECU = 10^{16} electrons/m^2. The grey circles point to the location of the M$_w$ 7.6 earthquake and the dashed red circles define the earthquake preparation zone [24].

B. The EIA Shape

Due to the low-latitude location of the seismic incidents the sky above this geographic region is also subjected to the Equatorial Ionization Anomaly (EIA) [26]. [27] have indicated that the latitudinal shape of the EIA can undergo some variations before a strong earthquake. Three modifications were proposed by [27]: enhancement of the EIA, vanishing of the crests, and shifting of the EIA. In view of this, a meridian section at 71°W was selected for the period of days between November 19 and 24, 2015 at 18:00 UT (Fig. 6). This hour was chosen because at 18:00 UT (13:00 LT) on November 22, a positive ionospheric anomaly at its most intense moment was observed (Fig. 4).

In Fig. 6 it can be seen that for November 22 the EIA, which at this hour (18:00 UT) of the day is above the Peruvian sky, significantly increases showing a sharper definition of the double-crest with a trough shape. The rest of the selected days, November 19, 21, 23 and 24 remained in a non-disturbed state. However, on November 20 (4 days before the two earthquakes), it can be observed as well a considerable increase of the EIA. Thus, looking into the ΔVTEC maps for this day (Fig. 7), two positive anomalies can be observe appearing on November 20 at 20:00 UT and completely disappearing on November 21 at $\sim$08:00 UT. On November 21 at 00:00 UT, it can be observed that a negative ionospheric anomaly appears well-within the preparation region and in between both positive anomalies. Hence; it is clear that at this time, 00:00UT (19:00

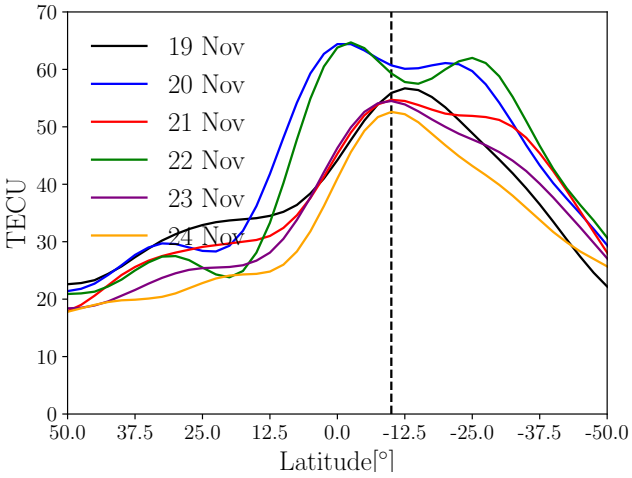

Fig. 6. Structure of the VTEC for the 71°W meridian at 18:00 UT between November 19 and 24, 2015. A relevant range of latitudes is shown, 50°N–50°S. The vertical dashed black line indicates the latitude 10°N, approximately where the two earthquakes took place.

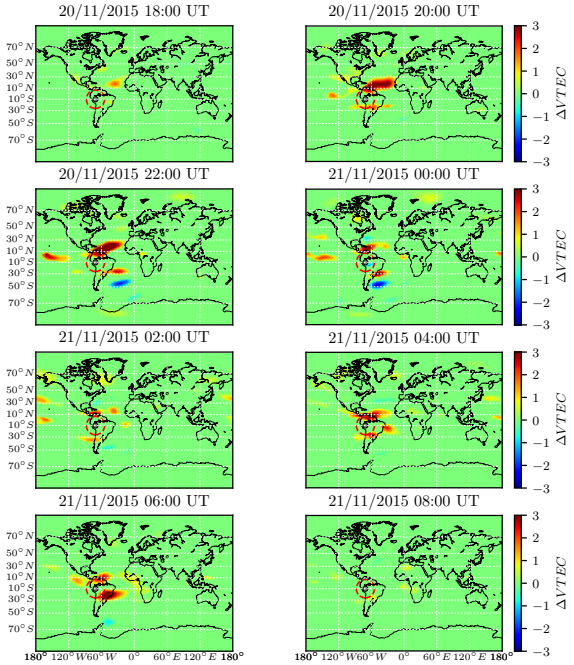

Fig. 7. Differential VTEC global maps for the period between November 11, 2015 at 18:00 UT and November 21, 2015 at 08:00 UT. The grey circles point to the location of the M_w 7.6 earthquake and the dashed red circles define the earthquake preparation zone [24].

LT), both positive anomalies and negative anomaly correspond actually to the modification of the EIA shape observed in Fig. 6 for November 20 at 18:00 UT, the double-crest with a trough shape. Authors in [2] have also observed a similar deformation of the EIA during night hours a few days before the September 26, 2005 earthquake in Peru. Another example of the modifications of the EIA during night and day time into a well defined double-crest with a trough occurred 1 and 2 days before the December 26, 2004 earthquake in Indonesia [1].

In Fig. 8 it can observed that the positive ionospheric anomaly observed in Fig. 5 on November 23 at 10:00 UT (05:00UT), before sunset, shows an increment of the VTEC. The other selected days, before and after (November 19, 20, 21, 22 and 24), remained stable.

C. Origin of the Seismo-Ionospheric Signatures

As indicated by [21], the M_w 7.5 and M_w 7.6 earthquakes occurred in the same fault. Hence, it is safe to assume that the days before in which seismo-ionospheric signatures were observed can be considered to be a product of the preparation to the two earthquakes. Looking at the geomagnetic activity (Fig. 2) between November 20, 2015 and the day the earthquakes happened (November 24, 2015), one can observe that this remained very quiet (Dst $>$ -20 nT and Kp $\leq$ 3). Thus, it can be suggested that the three observed positive ionospheric anomalies, November 20 (20:00 UT) - 21 (06:00 UT), November 22 (14:00-18:00 UT) and November 23 (08:00-12:00 UT), are precursors of the earthquakes.

In order to explain why an increment of VTEC is observed in these three days as a product of the earthquakes' preparation, a model that works with air ionization due to radon's release from the Earth's crust is considered [28], [29]. Radon emanating from the crust towards the Earth's surface and the air will cause the ionization from the latter. Afterwards, depending on the ionization levels in the lower atmosphere, the air conductivity will increase or decrease. When the air conductivity decreases, the ionosphere potential increases, and it is in this case when positive ionospheric anomalies can be observed. The concentration of radon has already been observed to increase many days before some major earthquakes [30], it would then remain to see if that is the case for the earthquake doublet.

V. Conclusions

Using GIMs provided by CODE, ionospheric anomalies were investigated prior the earthquake doublet that happened in Peru on November 24, 2015. First, by generating global differential VTEC maps, two ionospheric anomalies, at a confidence level of 95%, were observed 2 (November 22, 2015) and 1 (November 23, 2015) day prior to the seismic events. Both positives anomalies were observed to fall inside the earthquake preparation zone define by the Dobrovolsky equation [24]. Due to the low-latitude nature of the earthquakes, 10.54°S and 10.06°S, the shape of the equatorial ionization anomaly was also analyzed. By looking into the EIA, it was not only possible to confirm the ionospheric disturbance observe on November 22, 2015, but it was also possible to identify a third anomaly that occurred between November 20 (20:00 UT) and November 21 (06:00 UT). As for other major earthquakes previously studied at low-latitudes, in this case it was possible to observe as well how the EIA shape was modified, through the increase of the VTEC and a sharper definition of the

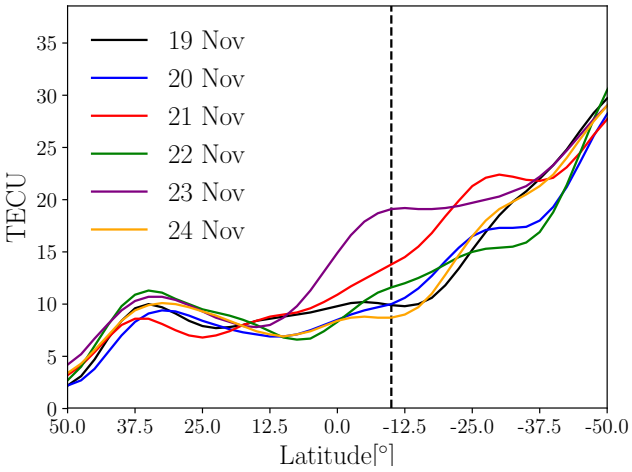

Fig. 8. Structure of the VTEC for the 71°W meridian at 10:00 UT between November 19 and 24, 2015. A relevant range of latitudes is shown, 50°N–50°S. The vertical dashed black line indicates the latitude 10°N, approximately where the two earthquakes took place.

double-crest with a trough shape, which is expected to be seen during daytime. These findings along with the fact that the geomagnetic conditions starting on November 20, 2015 remained very quite (Dst $>$ -20 nT and Kp $\leq$ 3), reveal that these three disturbances are seismo-ionospheric signatures to the earthquake doublet. It is very likely that air ionization due to the release of radon may be the originating mechanism for the observed positive ionospheric disturbances. Finally, the detection of these anomalies should provide a further insight in the detection of seismo-ionospheric signatures for very deep earthquakes.

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NetMob: A Mobile Application Development Framework with Enhanced Large Objects Access for Mobile Cloud Storage Service

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***Abstract*—Mobile enterprise applications are primarily developed for existing backend enterprise systems and some usage scenarios require storing of large files on the mobile devices.These files range from large PDFs to media files in various formats (MPEG videos).These files needs to be used offline , sometimes updated and shared among users. Present work studied different Mobile Backend as a service (M)BaaS platforms to understand techniques use to handle large file and found that many are either missing the feature or does not handle performance issues for large files. In this paper, we are proposing, NetMob, a mobile synchronization platform that allows resource-limited mobile devices to access large objects from the cloud. This framework is mainly focused on large file handling and has support for both table and objects data models that can be tuned for three consistency semantics, resembling strong, causal and eventual consistency. Experimental results conducted using representative workloads showed that NetMob can handle large files access with the size ranging from 100MB upto 1GB and is able to reduce sync time with object chunking in our experiment settings.**

***Keywords*—Mobile cloud computing; data consistency; mobile back-end as a service; mobile apps; distributed systems**

I. Introduction

In general, mobile cloud computing architecture has two unique set of entities namely Fixed Hosts (FHs) and Mobile hosts (MHs) [1]. FHs are machines (Works stations and Servers) with efficient computation power and reliable storage of data and run large databases. FHs that are connected through fixed network. MHs with limited processing and storage power (cellular phone, palmtops, laptops, notebooks) are not continually communicating with the fixed network. They may be disconnected for various reasons.

Additional dedicated fixed hosts called mobile support stations (MSSs) acts as the channel between the FH and MH through wireless LAN (local area network) connections, cells or connections to the network with standard modems.

When the network connectivity becomes unavailable or unacceptable, the MH enters the disconnected state. Disconnected operation (see Fig. 1) is a three-stage changeover between the following states [2].

1) Data hoarding : This is the process of preloading or prefetching the data in anticipation of a foreseeable disconnection. Before going to offline mode (disconnection), the data structures necessary for operation during disconnection are either replicated (catched) or moved (partitioned) at the MH.
2) Disconnected operation: When the MH is offline (disconnected from the network), data might be changed, added or even removed at either the MH or the FH.
3) Synchronization or Reintegration : When the connection is reestablished, each operation executed at the MH should be synchronized (reintegrated) with appropriate updates executed at other sites in order to attain seamless consistency.

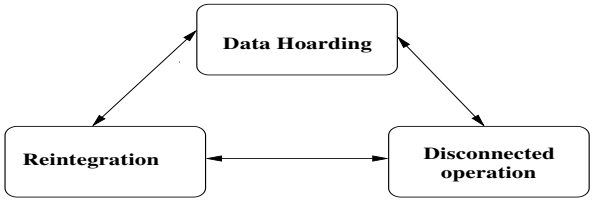

Fig. 1. States of Disconnected Operation.

For a given distributed system, the complexity of operations in each of above the three states is determined by the interdependence of data operated on. The execution of distributed applications in local-area networks is significantly different than in wireless, mobile systems. Wireless applications must use different communication pattern in order to address the high latency, low bandwidth, intermittent connections and communication charges based on time and content.An application operating on a LAN can manage good user interactions in case queries to a non-local database, but the same application operating on a wireless network may become unresponsive due to the delay in response. Hence wireless applications chose data replication, explicit or implicit (caching or data hoarding), as the primary technique to address the Disconnected operation.

The introduction of multi-user and collaborative features for wireless application increase the complexity, as multiple users have to share data objects and thus communicate and collaborate with each other [3]. In such cases there must be a sophisticated coordination mechanisms other than the conventional mechanism of locks. Thus addressing the wireless mobile systems constraints in the application development becomes challenging for developers, since they have to retain favorable user interaction and performance along with tackling

the data coordination issues.

Mobile services can be developed and deployed in various cloud computing scenarios. The main service models of cloud computing are [4] Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). With the advent of new service model, Backend as a Service (BaaS), sometimes also referred as Mobile Backend as a Service (MBaaS), the native mobile applications can be easily integrated with the cloud. MBaaS frameworks should:

- Facilitate non blocking, responsive (ensure high availability) and reliable mobile applications during disconnection.
- Support Cloud-connected multi-user, shared-data mobile apps that require to handle the inter-dependent data locally,and also across multiple devices with cloud storage.
- Provide a synchronization model with tunable consistency guarantees so that developers have the flexibility to configure how data is synchronized and data conflict are handled.
- Provide a synchronization-aware high-level APIs that support applications for on demand and background synchronization tasks.
- Enable support for large files (i.e. a couple of megabytes or gigabytes) synchronization.
- Require to be efficient in power consumption and bandwidth usage for mobile clients and carry out efficient periodic/configured sync operations.

Each MBaaS system offers a distinctive set of functionalities through APIs (REST or wrapper libraries of the APIs) and allows programs to be written specially to execute in the cloud. Amazon Mobile SDKs provide the means to interact with cloud services through REST APIs. Multi-platform SDKs (iOS, Android, Fire OS, and Unity) are offered to interact with the AWS services, including S3 (storage), DynamoDB (database), Simple Notification Service (SNS) and Mobile Analytics [5] . Apple provide iCloud service (CloudKit SDK) to store and access data in iCloud [6]. Mobile applications are broadly classified into two types such as offline applications and online applications [7]. Unlike online apps,in offline (native) application, the mobile device and back-end system are not connected always. In order to support continuous mobile services, offline applications will process the presentation and business logic with the available local data on the device itself. Periodically data is updated by synchronizing with back-end systems.

Recently a large number of research efforts have been conducted on enterprise cloud storage services and personal cloud storage services. The investigations from [8] attempted to find out mobile user access behavior in a large-scale mobile cloud storage with a a dataset of 350 million HTTP request logs. The study observed the trend of using the cloud storage for large file sharing, with the average volume as large as about 70 MB, in multiple sessions for retrieving one file.

Another study from a cloud storage service provider (Filestack [9]) analyzed a dataset of 100,000 applications.They provided the services of handling file uploads, transformations, storage, and delivery.Their observation targeted the statistics of uploaded trend of files ranging from different sizes and formats from the year 2015 to 2016 as shown in Fig. 2.Their analysis concluded that all file increased 50% year over year, but files sized 100MB and above increased over 170% year over year. This leads to the conclusion that file sizes are getting larger and mobile users access or share large size of files (above 100MB).

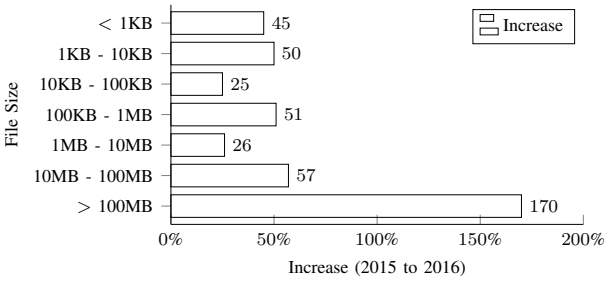

Fig. 2. Increase in files uploaded by File size

Handling the task of uploading and retrieving large files from and to a mobile app is a cumbersome process for developers due to issues of latency, speed, timeouts and interruptions. With the growing prevalence of sharing file of larger sizes among mobile users, providing reliable and efficient synchronization service for large files has become an important feature.

The rest of this paper is organized as follows: Section II discuss about the related work with details of support for large files upload and retrieval in mobile data synchronization frameworks with cloud storage services. Section III describes in detail the proposed framework, NetMob, a cloud based framework to support End-to-end data consistency for large data object access. Section III deal with architecture and design in detail along with details of NetMob data model and supported APIs. Section IV deals with the technique of handling the large objects with Segmentation and Object Chunking for object storage in Open Stack Swift [10]. While the Section V describes the NetMob handling of large object support with Segmentation and Object Chunking both at the client and server side, Section VI illustrate NetMob support for the consistency schemes with Cassandra [11] and Open Stack Swift [10]. Section VII discuss about the NetMob implementation followed by Evaluation (Section VIII & Section IX) with comparison of NetMob with Dropbox, and Conclusion and future work (Section X).

II. Related Work

Supporting large file upload and retrieval is crucial for the mobile cloud storage services, as file sizes are trending larger and mobile users access or share files of large size [8], [9]. Practical large object services are, however, only available for PC clients and not for mobile apps. To understand the support for large file objects, we analyzed both the commercial and open source cloud storage services for mobile. Table IV summarizes the large objects support and limitations in the different reference implementations. Even though the commer-

cial cloud frameworks provide support for large objects, many frameworks do not handle large files.

The key observation from the study is that many of the systems do not support large objects and some have limitations.

Simba's [12] sync protocol does not support streaming APIs to handle big size objects (e.g. Media file like Videos). SwiftCloud [13] is a middleware system that implements a Key-CRDT on top of Riak [14]. The Riak designers do not recommend storing objects over 50MB for performance reasons. Izzy [15] is an initial version of Simba and do not support large objects.

Mobius [16] does not handle large files but addresses the messaging and data management challenges of mobile application development. Special CRDT cloud types data in TouchDevelop [17], [18] do not address large size.

Open Data Kit 2.0 [19] which is an Android based service have a 1 MB size limit on remote-procedure calls.To address 1MB limit, ODK Kit implements a primitive transport-level chunking interface using a client-side proxy to bring together the chunks and only reveal a higher-level abstraction to the tools.

QuickSync [20] framework is built using Dropbox and Seafile APIs that supports large data size up to 180MB. The *chunked_upload* API supports uploading of larger files in multiple chunks. It supports the interrupted uploaded to be resumed later with chunk of any size up to 150 MB with a default size of 4 MB.

The Parse Server [21] only supports files up to to 10MB. The ParseFile data type allows the app to store application files in the cloud in addition to a smaller data structure of ParseObject. PareObject allows upto to 10MB data in bytes array or in the Stream form and SaveAsync call saves the file to Parse.

BaasBox [22] which is an open source MBaaS framework does not support large files. It is based on Play framework which is a lightweight, stateless, web-friendly architecture. In order to support large files, the REST APIs in Play framework can be configured for the maximum payload size in POST operations. Body parsers in Play framework is a HTTP request (at least for those using the POST and PUT operations) that contains a body. The default size of POST request is 100KB and can be configured according to the server configuration.

Dropbox [23] REST APIs supports large files up to 150MB. The *files_put* API has a maximum file size limit of 150 MB and does not support uploads with chunked encoding. The *chunked_upload* API support uploading of larger files in multiple chunks. Chunks can be of any size up to 150 MB with a default size of 4 MB. Dropbox supports resuming uploads if interrupted due to network disconnections.

Google Drive [24] APIs supports resumable uploads for files more than 5MB, with a single request or in multiple chunks.The PUT request allows chunks in multiples of 256 KB (256 x 1024 bytes) in size, except for the final chunk that completes the upload. Chunks size has to be kept as large as possible so that the upload is efficient.

Amazon Dynamo [25] provides high availability allowing updates even during the network partitions or server failures and targets applications that require only key/value access. Amazon DynamoDB enforce a maximum item size of 400KB in a table, including both attribute name binary length and attribute value lengths. If the application needs to store more data in an item than the DynamoDB size limit permits, the app can try compressing one or more large attributes, or it can store them as an object in Amazon Simple Storage Service (Amazon S3) and store the object identifier of S3 in the DynamoDB item.

The documentation of iCloud supported by CloudKit [6] neither specify a Document file size limit, nor a Core Data (iOS local) storage limit, other than a user account icloud storage allowance. But the uploads are dependent on the storage limit of device/user iCloud account. When the app adopt iCloud document management lifecycle, the operating system (iOS) initiates and manages uploading and downloading of data for the devices attached to an iCloud account. The app does not directly communicate with iCloud servers and, in most cases, does not invoke upload or download of data.

The commercial framework Kinvey [26] supports to store and retrieve binary files of size up to 5TB with the help of third-party service. Kinvey currently use Google Cloud Storage, as a third-party service to provide short-lived links, that can be used to upload or download files.

Kony [27] is another platform that supports Large Binary Objects API to retrieve and delete large binary objects, schedule a download, and get the location of the objects. While the Sync Chunking Mechanism applies to all of sync, the Large Binary Objects API supports the download of binary data stored in a particular object in multiple chunks. The download occurs in the background, allowing the user to perform tasks simultaneously.Kony applies Byte Range Serving technique, where a client can request a specific portion of Large Binary file that is present on the backend. This technique efficiently uses the network bandwidth by allowing user to download the binary in chunks ranging over multiple requests to the server.

Prior work from the authors of this paper [28] presented a review of data consistency and synchronization frameworks in Mobile Cloud Computing for Mobile Apps. This work was focused on client-centric data consistency and the offline data synchronization feature of various frameworks. While previous work from the same authors covers results from the selected studies in areas such as data consistency, handling offline data, data replication, synchronization strategy, this paper deals with only large file handling support.

III. NetMob

To meet mobile application development requirements and with main purpose of supporting large files (i.e. hundreds of megabytes or gigabytes or more), we have developed NetMob. NetMob is an applications framework, implemented in C# and centered around the main aspect of providing the support for large files (from hundreds of MBs up to 5GBs) in mobile cloud services and enable the programmers to create arbitrarily complex, synchronized replicated large data objects.

A. NetMob Architecture and Design

NetMob architecture consists of mainly two modules. One Client software executes on the mobile device and the other

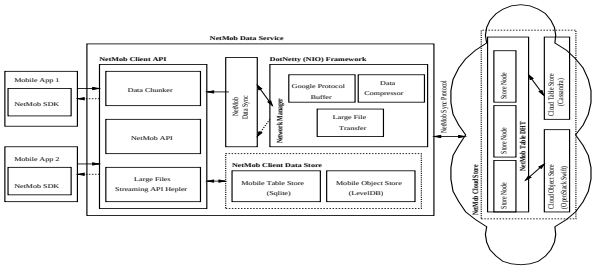

Fig. 3. Architecture of NetMob framework.

server for data storage in the cloud. The combination of these two software assists the development of mobile application on the device according to the NetMob SDK. Fig. 3 shows the basic architecture of NetMob.

The NetMob System Data Control Service (Nm-SDCS) is the client software which acts as a interface of device-to-cloud communication, for the mobile apps and responsible for exchanging data and messages with the with NetMob Cloud Data Server through a custom sync protocol. Each NetMob app communicates with the system-wide service of NetMob System Data Control Service, through the NetMob Data API (streaming and CRUD) provided by the NetMob SDK.Nm-SDCS service also consists of NetMob Local database store (Nm-LDBS) to save all the application data and metadata inside tables or object store.The local database store (Nm-LDBS) is managed by Nm-SDCS and is not directly accessible to NetMob apps.

The cloud server consists of NetMob Cloud Data Server (Nm-CDS) which store the data and interact with the data control service via custom sync protocol.

To reduce network footprint,the Network Data Manager (NMD) helps to transmit network data (from multiple rows, across multiple objects/tables) and messages from multiple apps with data compression and support for large file transfer.

The key design goals supported by NetMob architecture are as follows:

1) NetMOB SDK provide programming model familiar to mobile app developers with Data API consisting of CRUD and sync systematic along with unique support for streaming access to large objects.The complexities of disconnected operations, data hoarding, conflict detection and push notifications are hidden behind this interface.
2) NetMob provide a high level abstraction for building a fault-tolerant apps and assist apps to programatically handle delay-tolerant data transfer between the mobile device and the cloud.A non-zero period value of delay tolerance (DT) can be set which determines the frequent of change collection.
3) NetMob SDK provides apps with data granularity of both tables and object data with a feature to specify the distributed consistency for the data.
4) NetMob utilize efficient data reduction and bandwidth reduction techniques to minimize both the number of messages and bytes transferred over the network and hence support efficient device battery usage.

B. Data Model

NetMob's data model simplifies data storage for apps to store all of their data and hiding the details of how data is stored and synced.NetMob offers a data model called NetMob Table (Table$_{NM}$ for short) supporting both tables and objects. An individual row of an Table$_{NM}$, called a Row$_{NM}$. Each Row$_{NM}$ can accommodate associated tabular and object data with the tunable distributed consistency for the table as a whole from available consistency options. Hence NetMob permit consistency specification per table and treat a row as the unit of atomicity preservation. Same consistency is applicable to all tabular and object object data in Table$_{NM}$. NetMob ensure that all app and user data stored in the Table$_{NM}$ and provide synchronization service with the cloud and on to other mobile devices.

NetMob can also support apps that need either a tabular-only or object-only schema.NetMob also frees the developer from writing complicated transaction management and recovery code by utilizing the Row$_{NM}$, which offers a programmable higher-level interface,for a unit of app data with consistency guarantees under all scenarios.

C. API Interface

The design of NetMob API is similar to the well-known CRUD interface and enable the apps to set the Table/Object properties, access their data and push new data and perform conflict resolution.NetMob a stream abstraction that allows the objects to be written to, or read from, which is very suitable to handle large object. NetMob also support local reading or writing only a part of the large object , which is not supported by typical BLOBs (binary large objects) in relational databases [38]. Any app written adhering to this API interface is considered as a NetMob-app.

API, described in Table I, provide following features:

1) CRUD (Create, Read, Update, and Delete) functionality on both tables and objects.
2) Methods to subscribe tables for synchronization.
3) Notifications for new data and conflicts.
4) Support for conflict detection and facility for resolution.

D. NetMob Design

1) NetMob Client (Client$_{nm}$): Client$_{nm}$ allow the networked NetMob-apps to have I/O data model even during the disconnected operations and enable partition tolerance. Client$_{nm}$ allows seamless data access for the apps by hiding the them from server and network disconnections. It is designed to run as static instance of device-wide service with following functionalities:

1) Provides seamless access to table and object data for all NetMob-apps through a well defined lightweight Interface (sClientLib).
2) Support large objects with stream abstraction to read and write objects.
3) Maintain appropriate local replication of data on the mobile device to enable disconnected operations.

TABLE I. **NetMob APIs.**

Type	API	Purpose
CRUD Operations on tables and objects	PutObject[]	Creating Objects
	GetObject[]	Retrieving Objects
	PutObject[]	Updating Objects
	DeleteObject[]	Deleting Objects
CRUD Operations with Chunking	PutObjectChunk[]	Creating chunk
	GetObjectRange[]	Retrieving chunk
	DeleteObjectChunk[]	Deleting chunk
	DeleteChunks(table, selection)	Deleting multiple chunks
Large Object Handling	PutManifest[]	Creating large objects using Chunk
	GetManifest[]	Retrieving large objects using Chunk
	DeleteObjects[]	Deleting large objects
Object Synchronization	writeSyncSubscribe(table, period, delayTolerance, syncprefs)	Register for sync notifications
	writeSyncUnSubscribe(table)	Unregister for sync notifications
	instantWriteSync(table)	Invoke instant Write Sync
	readSyncSubscribe(table, period, delayTolerance, syncprefs)	unregisterReadSync(table)
	instantReadSync(table)	Invoke instant Read Sync
Notification APIs	dataAvailableFresh(table, numRows)	Notification for new data availability
	conflictData(table, numConflictRows)	Notification for conflict in data
Conflict Resolution	beginCROperation(table)	Start Conflict resolution
	getConflictedDetails(table)	Get conflicted Details
	resolveConflict(table, row, choice)	Resolve Conflict
	endCROperation(table)	End Conflict resolution

4) Guarantee fault-tolerance, high availability, data consistency, and atomicity at row-level.
5) Execute all synchronization tasks over the network.
6) Provide notifications to the apps for events like new data, conflict.
7) Monitors liveness of apps, and memory management in case of app crashes.

2) NetMob Local Data Store ($LDBS_{NM}$) : The NetMob Local Data Store ($LDBS_{NM}$) act as a local persistent storage module to save both tabular data and objects of app in the mobile device's memory (typically the internal flash memory or the external SD card). The primary responsibility of ($LDBS_{NM}$) is to support atomic updates over the local data and allow efficient CRUD operations support (on $Rows_{NM}$). It also support atomic sync of variable sized and possibly large objects. It must respond quickly to the change detection queries and inform about the sub object changes in the stored local data. The data layout of $LDBS_{NM}$ is shown in Fig. 4. The logical structure of the table and object storage is also depicted in Fig. 4.

The primary goal design of $LDBS_{NM}$ is to enable storage of large objects by dividing local data into fixed-size chunks and store in a key–value store (KVS) that supports range queries. LevelDB [29], a KVS based on a log-structured merge (LSM) tree [30] is chosen, that has a good throughput for both appends and overwrites.

3) NetMob Cloud Server ($Cloud_{NM}$) : The primary responsibility of NetMob Cloud Server (called $Cloud_{NM}$) is to manage data across multiple $Client_{NM}$, $Table_{NM}$, and NetMob-apps. $Cloud_{NM}$ facilitate tunable consistency storage mechanism

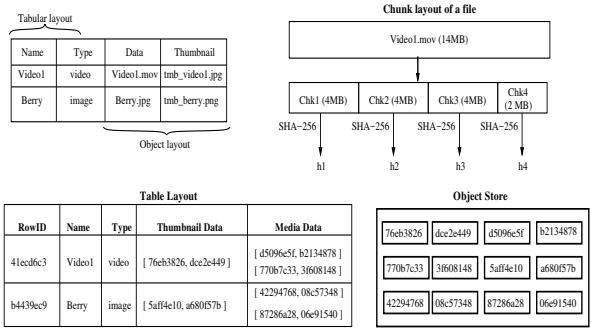

Fig. 4. NetMob Local Data Store.

with three different consistency plans and synchronization for $Table_{NM}$.

$Cloud_{NM}$ is divided into two modules,client-facing Gateway and a data store, NetMob Cloud Store (for short, $Store_{NM}$), based on independently scalable client management and data storage, respectively. For data scalability,store is organized into store nodes. At-most one Store node is assigned to each $Table_{NM}$ to manage both its tabular and object data.In order to ensure read-my-writes consistency [31] with scalability, the data of $Table_{NM}$ is saved in two separate stores, each for tabular and object data. The store nodes server the client requests by serializing the synchronization operations and support three different consistency plans on each table at the server.

The Gateway acts as an interface for the communication between $Client_{NM}$ and the $Cloud_{NM}$. The load balancer assign a Gateway for the requested clients and handles authentication of client through an authenticator. The Gateway handle the table subscriptions, sending notifications, communication of the clients and transfer sync data between $Clients_{NM}$ and $Store_{NM}$. Since the Gateway is subscribed to change notifications for all $Store_{NM}$ nodes and eventually gets notified on changes to a subscribed $Table_{NM}$.

E. Sync Protocol

The design goal of $Cloud_{NM}$ is to communicate with the clients both for storage as well as data synchronization.Hence it interacts with the $Client_{NM}$ in the terms of change-sets.NetMob synchronization protocol is built on Netty [32] framework that support better throughput and lower latency. Netty has protocol support for transferring large files using zlib/gzip compression and data transfer through Google Protobuf [33].

Any client that require to communicate with each table of interest , needs to register with the server by subscribing to a write and/or read subscription. The design of sync protocol handle multiple independent writers using versioning to provide multi-version concurrency control through $Cloud_{NM}$. $Cloud_{NM}$ use the technique of compact version numbers, instead of full version vector [34] in order to support StrongS and CausalS consistency schemes.

For efficient change identification, NetMob keeps a version number per row and assign a unique row identifier. NetMob follows the scheme is used in gossip protocols [35] to identify that rows that needs to be synchronized.With each update

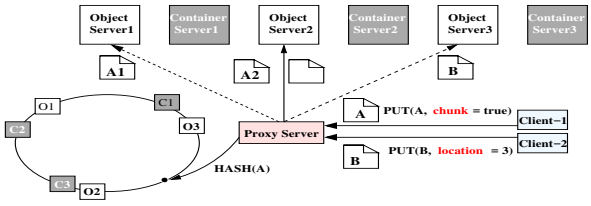

Fig. 5. NetMob cloud server Object Chunking in OpenStack Swift.

of the row,Row versions are incremented at the server. NetMob set the largest incremented row version maintained in a table, as the table version. Based on this table versioning scheme NetMob immediately determine which rows need to be synchronized and also select the list of $Rows_{NM}$ which are modified, or the change-set.

For efficient network transfer, NetMob use the chunking methods and objects are stored and synced as a collection of fixed-size chunks.Client APIs expose chunking and apps continue to locally read/write objects as streams.

NetMob design is derived from previous work of unified table and object interface in the context of local systems [36] as well as in a networked app ([15], [12], [37] and [38]).

IV. Large Object Support with Segmentation and Object Chunking

The Chunking mechanism allows NetMob clients to transparently split objects into smaller parts, when uploading data to the object storage. In order to support upload of large objects, in Object Storage, the Open Stack Swift [10] use segmentation process. The process of Segmentation involves dividing the object and accordingly generating a file that delivers the segments together as a single object. Segmentation allows a virtually unlimited size of single object upload with faster and opportunity of parallel uploads of the segments.

OpenStack Object Storage allows single item of up to 5 GB in size for uploading. Openstack Swift follow segmentation process by fragmenting the object, and automatically creating a special manifest file that sends the segments concatenated as a single object. The technique of splitting objects into smaller chunks not only increase the efficiency and facilitate parallel uploads and also transparently support small, equal-sized chunks.

Fig. 5 illustrates the process of segmentation. During the upload, a client can request for object chunking and the proxy server split the arriving data into several blocks. These different blocks will be internally named based on the placement in the cluster. A special manifest file is generated with the ordered list of the names of all object blocks. During the GET request, the proxy sends the parts in order to the client, by reading the manifest file.

V. Large File Handling

The network manager implemented using the .Net DoTNetty uses zip (zlib/gzip) data compression with Google protobuf support and also provide support for large file transfer.

A. Large Object Support with Segmentation

In order to support upload of large objects, in Object Storage, the Open Stack Swift [10] use segmentation process. The process of Segmentation involves dividing the object and accordingly generating a file that delivers the segments together as a single object. Segmentation allows a virtually unlimited size of single object upload with faster and opportunity of parallel uploads of the segments.

Each object is stored as a single file on disk unless its size exceeds the maximum file size configured for the Swift cluster. This maximum file size defaults to a rather small value, 5 GB, in order to prevent a single object from filling up a disk while most of the cluster is empty. If an object to be stored is very large, it is divided into several segments and stored with a manifest to allow reassembly later.

B. Client Side Large Objects Handling in LevelDB with LSM

At the client side, NetMob integrate SQLite for table data and LevelDB for objects.NetMob embeds LevelDB at the mobile side for handling the large files.LevelDB use the concepts of Sorted String Table, Log Structured Merge (LSM) to support processing large workload where the input is in Gigabytes in size.

Sorted String Table (SSTable) [39] is popular data structure for efficiently storing large numbers of key-value pairs and support high throughput with sequential read/write workloads. SSTable can process and exchanging datasets where the input is in Gigabytes in size.

This Log Structured Merge (LSM) [30] architecture provides a number of interesting behaviors in combination with the SSTable. Since the LSM allow all writes go directly to the MemTable index, write operations are always fast regardless of the size of dataset (append-only). Also the random reads are either quickly retrieved from memory or served from disk (search MemTable initially and then the SSTable indexes. The MemTable is regularly flushed into disk as SSTable.

LevelDB architecture combines a set of processing conventions applied to SSTable and a MemTable to create a powerful embedded database engine. The other products that follow similar architecture are Google's Cassandra, BigTable, and Hadoop's HBase.

LevelDB supports fast write operations regardless of the size of dataset, as the all writes go directly to the log and a MemTable. The log is periodically flushed into disk as sorted string table files (SST) of size upto 2MB. Each SST file is internally split into single readable block of size 4K. These blocks are structured such that end block is an index that points to the beginning of each data block and it is the key of the entry at the beginning of the block. A Bloom filter accelerate the lookup process and facilitate fast search of an index to determine the block that may have the desired entry. LevelDB in addition minimize the read costs by partitioning SST into sets, or levels. Levels are numbered starting from 0, and each levels beyond Level 1 is 10 times the size of the previous level.

VI. Consistency levels in Cassandra and Swift

NetMob supports three most commonly used consistency schemes Strong, Causal and Eventual, identical to the ones in

Pileus [40] as illustrated in Table II.

TABLE II. CONSISTENCY SCHEMES IN NETMOB

Operation	Strong	Causal	Eventual
Offline write permission	No	Yes	Yes
Offline read permission	Yes	Yes	Yes
Need Conflict resolution	No	Yes	No

NetMob support a tunable Cloud Table store through Cassandra [11], [41] that allows consistency levels to be controlled from the client while performing an operation. Cassandra supports both the eventual and strong consistency models. In order to ensure high-availability, Cassandra is configured to make use of three-way replication. For supporting strong consistency during reading, Casandra will be configured for ReadConsistency=ONE, that indicates the immediate response from the closest replica. Similarly for supporting strong consistency during writing, Casandra will be configured for WriteConsistency=ALL. This configuration make sure that for all replica nodes in the cluster for that partition, a write operation is written not only to commit log and also to memtable.

Since OpenStack Swift supports Eventual consistency by default, in order to enforce the strong consistency, Store_{NM} initially creates a new object and consequently deletes the old one after the updated Row_{NM} is committed. Store_{NM} attach a read/write lock to each Table_{NM}, in order to guarantee exclusive write access for update with additional concurrent access to multiple threads for reading.

VII. IMPLEMENTATION

A. Client

The prototype of $\text{Client}_{\text{NM}}$ is implemented as system wide service to provide data services to multiple apps with reduces network usage with compression techniques. $\text{Client}_{\text{NM}}$ is developed as a system wide service, which is connected by NetMob-apps through local remote procedure calls (RPC). $\text{Client}_{\text{NM}}$ integrate SQLite for table data and LevelDB for objects. Both data and push notifications between $\text{Client}_{\text{NM}}$ and Cloud_{NM} are served with a single persistent TCP connection.This single TCP connection will avoid insignificant connection establishment and teardown [[42]] from NetMob apps. $\text{Client}_{\text{NM}}$ also implements the client APIs for OpenStack Swift that covers most of the Swift APIs, and handles authentication and large object streaming.

B. Server

Store_{NM} prototype integrate Cassandra [41] to provide the tabular data support and utilize OpenStack Swift [10] APIs for Object storage.

Cassandra supports both the eventual and strong consistency models. In order to ensure high-availability, Cassandra is configured to make use of three-way replication. For supporting strong consistency during reading, Casandra will be configured for ReadConsistency=ONE, that indicates the immediate response from the closest replica. Similarly for supporting strong consistency during writing, Casandra will be configured for WriteConsistency=ALL. This configuration make sure that for all replica nodes in the cluster for that partition, a write operation is written not only to commit log and also to memtable.

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VIII. EVALUATION

For application frameworks the latency is a benchmarking factor to study the effect of high-level abstraction for efficient sync of mobile application data [43], [44], [45], [46]. Based on the literature [47] consistency models suitable for mobile environments are classified based on three deviation metrics. This classification is termed as 3D Design Framework [48], [49]. Three metric parameters form the three axes of the 3D Design Framework:

1) Numerical deviation: difference in number of updates applied to replicas.
2) Order deviation: difference in order of operations between replicas.
3) Staleness: delay until replicas see an update.

The actual deviations may differ depending on the level of inconsistency tolerated by the system. The 3D Design Framework classification resulted after applying the metrics to various consistency models [48]. A suitable consistency model can be devised based on the acceptable amount of inconsistencies. The axes do not contain concrete values, as these depend on the system. The nature of the system also determines the acceptable amount of inconsistencies.

The empirical evaluation and comparison of the NetMob framework is performed in three main categories:

- The efficiency of NetMob Sync Protocol.
- The performance of Cloud_{NM} Data API consisting of CRUD and chunking operations.
- Effect of consistency and latency.

A. Experimental Setup

The evaluation environment of NetMob included a set of virtual machines and mobile device client. A virtual machine (VM) setup with OpenStack Swift (Version 1.12.0.37) deployment with one proxy node and 4 storage nodes. The proxy node with Ubuntu 14.04 was equipped with Intel Xeon CPU and 4 GB RAM and storage nodes (Ubuntu 14.04) had Intel Xeon E5-2403 processors and 1 GB RAM. Another VM with Cassandra (Version 1.2.5) setup with Ubuntu 14.04 was equipped with Intel Xeon CPU and 2 GB RAM.The system was tested with Xiaomi RedMi 5 Plus Device, 4GB RAM running Android Oreo. Evaluation was done using a WPA-secured WiFi network, instead of 4G network.

TABLE III. NETMOB SYNC PROTOCOL OVERHEAD

# No of Rows	Size of object	Size of payload	Size of Message (% Overhead)	Size of Network Transfer (% Overhead)
1	None	1 B	101 B (99.009%)	132 B (99.242%)
	200 KiB	200 KiB	210.098 KiB (99.905%)	235 KiB (99.149%)
	100 MB	106.34 MB	106.59 MB (0.235%)	106.89 MB (0.515%)
10	None	100 B	2.41 KiB (96%)	694 B (85.6%)
	200 KiB	2048 MB	2210 MB (99%)	2510 MB (99%)
	100 MB	1034.34 MB	1035.85 MB (0.15%)	1037.65 MB (0.318%)

B. Sync Protocol Overhead

NetMob is designed with a primary requirement to support programmers with an interface that can assist in efficient sync of mobile application data, with special focus on large file objects.It must be ensured that NetMob must not add significant overhead during the sync process. NetMob promise an efficient sync protocol with limited overhead and is lightweight.

To test the efficiency of NetMob Sync protocol we measured the message size and network transfer size for varied payload sizes with combinations of tabular and object data. Table III depicts the cumulative sync protocol overhead with varied payload sizes. The empirical evaluation calculate overhead for a single synchronization request comprising of a single row and a group of 10 rows with different sizes of payload.

The test results revealed NetMob produces an overhead of 100 bytes for a baseline message. This request is composed of no object data, but a single row consisting of tabular data of 1 byte. However it is observed that due to data compression in NetMob, the overhead in the case of per-row baseline request is reduced by 76%, for batch operations of 10 rows into a single sync request. Moreover, the data transfer overhead eventually becomes negligible when the payload (tabular or object) size increases. This shows that NetMob sync protocol is lightweight and efficient especially with group/batched row operations.

C. Performance of NetMob Data Retrieval and Chunking APIs

The NetMob API interface was tested by the mobile client application to issue requests of writing (uploading), reading (downloading) and deleting large files of various size. The ability of NetMob to support large files through fixed-size object chunking was also evaluated through test cases that configure the chunk size while calling the NetMob APIs.

1) Create-Read-Delete API performance:
NetMob framework is tested for both combination and individual tests of create-update-delete queries for data. For the write benchmark, with files of varying sizes from 1MB to 1GB. File read tests are conducted to analyze the ability of NetMob to handle large data from 1MB to 1GB. Tests for deleting individual files are also carried out. The create-read tests are initially carried out with a default chunk size of 8MB. Fig. 6 (A) depicts the results of create-read-delete APIs of NetMob.

The graph shows a gradual variation of the latency with respect to increase in the size of the file. Also the upload APIs took more time than the download APIs since the time spent is acknowledgment and processing data during the upload operation. The upload time variation was less for the upload

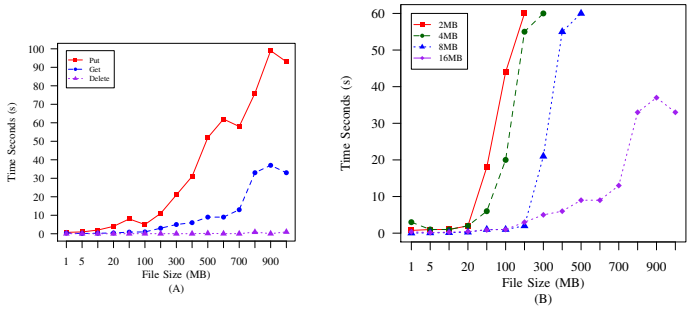

Fig. 6. (A)- Latency for Put, Get and Delete queries and (B) Put query latency for different chunk sizes (2, 4, 8 and 16 MB) in NetMob

file operations of size greater then 500MB, since the NetMob sync protocol effectively archive the data during network data transfer.

Delete operation for NetMob Clients is relatively fast, since lazy deletion marks objects as deleted. Overall, experimental evaluation of NetMob Data APIs showed that NetMob is efficient in handling the writing (uploading), reading (downloading) and deleting of large files.

2) Effectiveness of Object Chunking:
Next, we evaluated the performance of object chunking. To modify the object-to-node ratio, we use files of different sizes and change the object chunk size. A large file size produces a low number of objects with large chunk size and hence, a low object-to- node ratio or read-writes are faster. Fig. 6 (B) depicts NetMob performance of upload (Put query) operation with varying Object Chunk size.

Large chunk size proved to be more efficient as per the graph, since the large chunks produce fewer number of partitions of files hence can transmit faster. The authors recommend a chunk size of 16MB for NetMob for efficient large file handling, depending on the processing memory available in the mobile device.

D. Consistency vs. Performance

Cassandra supports both the eventual and strong consistency models. In order to ensure high-availability, Cassandra is configured to make use of three-way replication. For supporting strong consistency during reading, Casandra will be configured for ReadConsistency=ONE, that indicates the immediate response from the closest replica. Similarly for supporting strong consistency during writing, Casandra will be configured for WriteConsistency=ALL. This configuration make sure that all the writes must be written to both commit log and memtable on all replica nodes in the cluster, for that partition under consideration.

Since OpenStack Swift supports Eventual consistency by default, in order to enforce the strong consistency, Store_{NM} initially creates a new object and consequently deletes the old one after the updated Row_{NM} is committed. Store_{NM} attach a read/write lock to each Table_{NM}, in order to guarantee

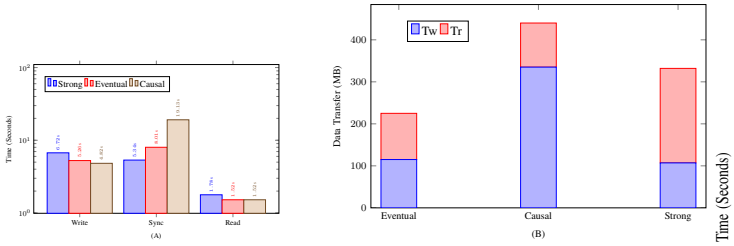

Fig. 7. (A) End-to-end latency for 100MB object and (B) Data transfer in different consistency schemes in NetMob

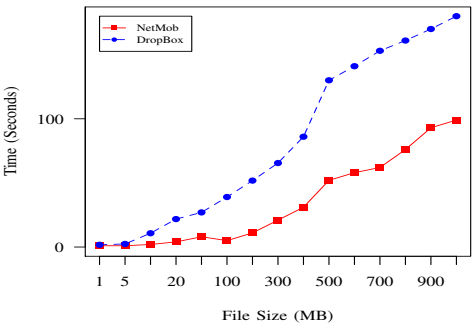

Fig. 8. **NetMob comparison with Dropbox framework for Upload data.**

exclusive write access for update with additional concurrent access to multiple threads for reading.

To measure the consistency parameters, the NetMob is tested with three types of mobile test clients Reader (Tr), Writer (Tw) and CausalTester (Tc). Prior to Tw's write operation, the client Tc have to make sure that it writes to a row which has the same row-key as Tw. This setup is tested with two Xiaomi RedMi 5 Plus Device, 4GB RAM running Android Oreo.The write payload is a 100MB file to measure the latency for reads, writes that is perceived by the NetMob client applications and latency of data sync with Cloud_{NM}. For evaluating the eventual and Causal consistency we used the notification time of one second. It must be ensured that all updates must happen prior to this time window.

Wi-Fi latency and associated data transfer are depicted in Fig. 7(A) and Fig. 7(B) respectively.

The "Write" latency is the app perceived latency of update at Writer (Tw). The sync-update latency from Writer (Tw) to Reader (Tr) is referred as "Sync". The "Read" latency is referred to the time taken by the app for reading updated data at Reader (Tr). Fig. 7(B) shows the total data transferred by Writer (Tw) and Reader (Tr) clients and for each consistency scheme.

Since Eventual_S consistency requires to read only the latest version, it turns out into a single sync process resulting in less data transfer according to the rule of last write. Strong_S consistency require all updates to propagate immediately, there is a higher data transfer, but has lowest sync latency as data is synced immediately.In case of conflicts,Sync latency for Causal_S is greater than Eventual_S , since the former requires more RTTs to resolve conflicts. Conflict resolution With CausalS increase the data transfer amount, since for the first sync attempt by Writer (Tw) fails, so Writer (Tw) must read CausalTester's (Tc) conflicting data, and retry its update. Sync latency and data transfer for Causal_S and Eventual_S are similar in case of absence of conflicts (not depicted).

IX. Performance Comparison with Other Sync Framework

The NetMob local performance is compared with the popular Data Syncing product Dropbox with chunk size of 16MB chunking. The test application invoke the writes, reads, and deletes for data containing one 100MB object for Dropbox (Core API) and NetMobClient. Fig. 8 shows standard deviation and average times and over three trials for the upload data (Put query). The Dropbox performance is affected by the location of the Dropbox server and the upload bandwidth at the time of testing. NetMob performs 15% faster than the Dropbox for the writes. The reason for the low performance of Dropbox may be due to server location (US) and the upload bandwidth at the time of testing. Delete performance for NetMob Client and Dropbox is almost same, since lazy deletion marks objects as deleted and but physically deleted only after sync operation is completed.

X. Conclusion and Future Work

Handling the task of uploading/retrieving large files from/to a mobile app is a cumbersome process for developers due to issues of latency, speed, timeouts and interruptions. In this paper, we investigated the large objects (from hundreds of MBs up-to 5GBs) support and limitations in the different reference implementations for cloud storage services for mobile. To address the large files, we propose NetMob, a framework with tunable chunking support and for large objects both at the mobile and the cloud storage. This work further contributed by implementing NetMob framework, that allows the large objects to be written to, or read from the cloud storage and also support local reading or writing only for a part of the large object, with tunable consistency option. The extensive evaluations demonstrate that NetMob can effectively store and sync large files with the reduced synchronization time and minimize significant traffic overhead for representative large file workloads. As a future work we would like to support additional consistency schemes (like Sequential consistency and others) in NetMob framework.

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APPENDIX

TABLE IV. SUMMARY OF LARGE OBJECT SUPPORT IN REFERENCE DESIGNS

Framework	LO Support	Max file upload size	Chunking	LO Handling Technique
Simba [12] *	✗	-	✗	Does not support large objects.
SwiftCloud [13]	✗	-	✗	✗ SwiftCloud is a middleware system that implements a Key-CRDT on top of Riak.The Riak designers do not recommend storing objects over 50MB for performance reasons
Indigo [50]	✗	-	✗	✗ Indigo is based on SwiftCloud..The Riak designers do not recommend storing objects over 50MB for performance reasons.
Izzy [15]	✗	-	✗	Izzy is an initial version of Simba and do not support large objects
Mobius [16]	✗	-	✗.	Does not handle large files but addresses the messaging and data management challenges of mobile application development.
TouchDevelop [17] * [18]	✗	-	✗	Special cloud types data do not address large size.
Open Data Kit 2.0 [19] *	✗	-	✓	Android Services have a 1 MB size limit on remote-procedure calls.To address 1MB limit, a primitive transport-level chunking interface using a client-side proxy to re-assemble chunks and only expose a higher-level abstraction to the tools.
StoArranger [51]	✗	-	-	Does not address large objects
QuickSync [20] *	179MB	✓	✓	QuickSync system is built on Dropbox and Seafile, cloud storage systems.Performance test included data size up to 179MB. Dropbox *chunked_upload* API support uploading of larger files of size 150 MB or more, in multiple chunks, with the feature of resuming if upload is interrupted. The chunk size is limited to 150MB and by default 4MB.
Parse Server [21] *	✗	10MB	✗	The ParseFile data type allows the app to store application files in the cloud that would otherwise be too large or cumbersome to fit into a regular ParseObject. PareObject allows data in bytes array or in the Stream form and SaveAsync call saves the file to Parse.
BaasBox [22] *	✗	100 KB	✗	BaasBox is based on java Play framework.BaasBox uses Play framework to manage REST. The Playframework Body parsers can be configured for the maximum payload size in POST operations. Body parsers is a HTTP request (for the POST and PUT operations) that contains a body. This body can be composed with any format specified in the Content-Type header.
Dropbox [23]	✓	150MB (REST API)	✓	Dropbox *chunked_upload* API support uploading of larger files of size 150 MB or more, in multiple chunks, with the feature of resuming if upload is interrupted. The chunk size is limited to 150MB and by default 4MB.
Evernote [52]	✓	5 MB-200 MB	-	Allowed upload size varies depending on the user type. In addition to text, notes can also contain attachments (called "Resources" in the Evernote API). These files can be of any file type.The attachment file is crated as a Resource object and added to the note. The documentation does not mention about chunking or upload of large objects.
Google Drive [24]	✓	Resumable upload for files more than 5 MB	✓	For larger files (more than 5 MB) or less reliable network connections, Google Drive support resumable upload with a single request or in multiple chunks.The PUT request allows chunks in multiples of 256 KB (256 x 1024 bytes) in size, except for the final chunk that completes the upload. Chunks size has to be kept as large as possible so that the upload is efficient.
iCloud with CloudKit [6]	✓	Documentation doesn't specify a file size	✓	When the app adopt iCloud document management lifecycle, the operating system (iOS) initiates and manages uploading and downloading of data for the devices attached to an iCloud account. The app does not directly communicate with iCloud servers and, in most cases, does not invoke upload or download of data.
Amazon DynamoDB [25]	✓	400 KB	✗	Amazon DynamoDB enforce a maximum item size of 400KB in a table, including both attribute name binary length and attribute value lengths. If the application needs to store more data in an item than the DynamoDB size limit permits, the app can try compressing one or more large attributes, or it can store them as an object in Amazon Simple Storage Service (Amazon S3) and store the Amazon S3 object identifier in the DynamoDB item.
Bluemix Mobile Cloud Service [53]	✓	-	✓	When handling transfers of large files content is streamed and sent in chunks.WLResourceRequest API for iOS has a helper WLResourceRequest.sendWithDelegate API that allows downloading of large files.The upload endpoint reads the client app uploaded large file in chunks and sequentially writes to a local file in the filesystem.The download endpoint connects to a backend server and downloads a large file in chunks. Each chunk is written to the endpoint output stream to be read sequentially by the client app.
Kinvey [26]	✓	Upto 5TB using Google Cloud Storage	-	Kinvey support to store and retrieve binary files of size up to 5TB with the help of third-party service. Kinvey does not directly serve or accept files. Instead, the Kinvey Files API works by providing a short-lived URL to a third-party cloud storage service from which file(s) can be uploaded or downloaded.Currently, the third-party service used is Google Cloud Storage.
Kony [27]	✓	20MB	✓	The Large Binary Objects API allows you to retrieve and delete large binary objects, schedule a download, and get the location of the objects. While the Sync Chunking Mechanism applies to all of sync, the Large Binary Objects API supports the download of binary data stored in a particular object in multiple chunks. The download occurs in the background, allowing the user to perform tasks simultaneously.Default chunk size is 4MB and configurable to set transfer buffer size.

Note:
*: open-source

Visualization and Analysis in Bank Direct Marketing Prediction

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***Abstract*—Gaining the most benefits out of a certain data set is a difficult task because it requires an in-depth investigation into its different features and their corresponding values. This task is usually achieved by presenting data in a visual format to reveal hidden patterns. In this study, several visualization techniques are applied to a bank's direct marketing data set. The data set obtained from the UCI machine learning repository website is imbalanced. Thus, some oversampling methods are used to enhance the accuracy of the prediction of a client's subscription to a term deposit. Visualization efficiency is tested with the oversampling techniques' influence on multiple classifier performance. Results show that the agglomerative hierarchical clustering technique outperforms other oversampling techniques and the Naive Bayes classifier gave the best prediction results.**

***Keywords*—Bank direct marketing; prediction; visualization; oversampling; Naive Bayes**

I. Introduction

Bank direct marketing is an interactive process of building beneficial relationships among stakeholders. Effective multi-channel communication involves the study of customer characteristics and behavior. Apart from profit growth, which may raise customer loyalty and positive responses [1], the goal of bank direct marketing is to increase the response rates of direct promotion campaigns.

Available bank direct marketing analysis datasets have been actively investigated. The purpose of the analysis is to specify target groups of customers who are interested in specific products. A small direct marketing campaign of a Portuguese banking institution dataset [2], for example, was subjected to experiments in the literature. Handling imbalanced datasets requires the usage of resampling approaches. Undersampling and oversampling techniques reverse the negative effects of imbalance [3], these techniques also increase the prediction accuracy of some well-known machine learning classification algorithms.

Data visualization is involved in financial data analysis, data mining, and market analysis. It refers to the use of computer-supported and interactive visual representation to amplify cognition and convey complicated ideas underlying data. This approach is efficiently implemented through charts, graphs, and design elements. Executives and knowledge workers often use these tools to extract information hidden in voluminous data [4] and thereby derive the most appropriate decisions. The usage of data visualization by decision makers and their organizations offers many benefits [2], that includes absorbing information in new and constructive ways. Visualizing relationships and patterns between operational and business activities can help identify and act on emerging trends. Visualization also enables users to manipulate and interact with data directly and fosters a new business language to tell the most relevant story.

The choice of a proper visualization technique depends on many factors, such as the type of data (numerical or categorical), the nature of the domain of interest, and the final visualization purpose [5], which may involve plotting of the distribution of data points or comparing different attributes over the same data point. Many other factors play a remarkable role in determining the best visualization technique that can detect hidden correlations in text-based data and facilitate recognition by domain experts.

The current research is an attempt to demonstrate the capabilities of different visualization techniques while performing different classification tasks on a direct marketing campaign. The data set, which contains 4521 instances and 17 features that including an output class, originates from a Portuguese banking institution. The goal is to predict whether a client will subscribe to a term deposit. The data set is highly imbalanced. Some oversampling methods are applied as a preprocessing step to enhance prediction accuracy. Random forest, support vector machine (SVM), neural network (NN), Naive Bayes, and k-nearest neighbor (KNN) classifiers are then applied. A comparison is conducted to identify the best results under Gmean and accuracy evaluation metrics.

The rest of the paper is organized as follows. Second section presents a review of the literature and the contributions of the bank direct marketing dataset. The third section provides a brief description of the oversampling techniques used in this research. Fourth section introduces details regarding the data set. Finally, the fifth section discusses the methodology followed in this research and the results obtained from running five different classifiers and their implications on the final prediction.

II. Related Work

From a broad perspective, the work in [6] surveyed the theoretical foundations of marketing analytics, which is a diverse field emerging from operations research, marketing, statistics, and computer science. They stated that predicting customer behavior is one of the challenges in direct marketing analysis. They also discussed big data visualization methods

for the marketing industry, such as multidimensional scaling, correspondence analysis, latent Dirichlet allocation, and customer relationship management (CRM). They debated on geographic visualization as a relative aspect of retail location analysis and tackled the general trade-off between its common practices and art. Additionally, they elaborated on discriminant analysis as a technique for marketing prediction. Discriminant analysis includes methods such as ensemble learning, feature reduction, and extraction. These techniques solve problems such as purchase behavior, review ratings, customer loyalty, customer lifetime value, sales, profit, and brand visibility.

Authors of [7] analyzed customer behavior patterns through CRM. They applied the Naive Bayes, J48, and multi-layer perceptron NNs on the same data set used in the current work. They also assessed the performance of their model using sensitivity, accuracy, and specificity measures. Their methodology involves understanding the domain and the data, building the model for evaluation, and finally visualizing the outputs. The visualization of their results showed that the J48 classifier outperformed the others with an accuracy of 89.40.

Moreover, [8] employed the same data set for other customer profiling purposes. Naive Bayes, random forests, and decision trees were used on the extended version of the data set examined in the current work. Preprocessing and normalization were conducted before evaluating the classifiers. RapidMiner tool was used for conducting the experiments and evaluation processes. They illustrated the parameter's adjustments of each classifier using a normalization technique applied previously. Furthermore, they showed the impact of these parameter values on accuracy, precision, and recall. Their results showed that decision trees are the best classifier for customer profiling and behavior prediction.

By contrast, [9] used the extended data set to create a logistic regression model for customer behavior prediction. This model is built on top of specific feature selection algorithms. Mutual information (MI) and data-based sensitivity analysis (DSA) are used to improve the performance over false-positive hits. They reduced the number of feature sets influencing the success of this marketing sector. They found that DSA is superior in the case of low false-positive ratio with nine selected features. MI is slightly better when false-positive values are marginally high with 13 selected features among a wide range of different features.

Additionally, a framework of three feature selection strategies was introduced by [10] to reveal novel features that directly affect data quality, which, in turn, exerts a significant impact on decision making. The strategies include identification of contextual features and evaluation of historical features. A problem is divided and conquered into sub-problems to reduce the complexity of the feature selection search space. Their framework tested the extended version of the data set used in the current work. Their goal was to target the best customers in marketing campaigns. The candidacy of the highest correlated hidden features was determined using DSA. The process involved designing new features of past occurrences aided by a domain expert. The last strategy split the original data upon the highest relevant set of features. The experiments confirmed the enrichment of data for better decision-making processes.

From visualization aspects, [11] explained several types of visualization techniques, such as radial, hierarchical, graph, and bar chart visualization, and presented the impact of human–computer interaction knowledge on opinion visualization systems. Prior domain knowledge yielded high understandability, user-friendliness, usefulness, and informativeness. Age factor affected the usability metrics of other systems, such as visual appeal, comprehensiveness, and intuitiveness. These findings were projected to the visualization of the direct marketing industry because it is mainly aided by end users and customers.

III. Oversampling Techniques

Oversampling is a concept that relates to the handling of imbalanced datasets. This method is performed by replicating or synthesizing minority class instances. Common approaches include randomly choosing instances (ROS) or choosing special instances on the basis of predefined conditions. Although oversampling methods are information-sensitive [12], they often lead to the overfitting problem, which may cause misleading classifications. This problem can be overcome by combining oversampling techniques with an ensemble of classifiers at an algorithmic level to attain the best performance.

An overview of the oversampling techniques used in the preprocessing phase of the current research, along with a brief description of the exploited classification algorithm, is introduced.

A. Synthetic Minority Oversampling Technique

Synthetic minority oversampling (SMOTE) generates synthetic instances on the basis of existing minority observations and calculates the k-nearest neighbors for each one [13]. The amount of oversampling needed determines the number of synthetic k-nearest neighbors created randomly on the link line.

B. Adaptive Synthetic Sampling Technique

Adaptive synthetics minority (ADASYN) is an improved version of SMOTE. After creating the random samples along the link line, ADASYN adds up small values to produce scattered and realistic data points [14], which are of reasonable variance built upon a weighted distribution. This approach is implemented according to the level of difficulty in learning while emphasizing the minority classes that are difficult to learn.

C. Random Over Sampling Technique

ROS is a non-heuristic technique. It is less computational than other oversampling methods and is competitive relative to complex ones [15]. A large number of positive minority instances are likely to produce meaningful results under this technique.

D. Adjusting the Direction of the Synthetic Minority Class Examples Technique

Adjusting the direction of the synthetic minority class (ADOMS) examples is another common oversampling technique [15] that relies on the principal component analysis

of the local data distribution in a feature space using the Euclidean distance between each minority class example and a random number of its k-nearest neighbors aided by projection and scaling parameters.

E. Selective Preprocessing of Imbalanced Data Technique

The selective preprocessing of imbalanced data (SPIDER) technique introduces a new concept of oversampling [16] and comprises two phases. The first phase is identifying the type of each minority class example by flagging them as safe or noisy using the nearest neighbor rule. The second phase is processing each example on the basis of one of three strategies; weak amplification, weak amplification with relabeling, and strong amplification.

F. Agglomerative Hierarchical Clustering Technique

Agglomerative hierarchical clustering (AHC) [16] starts with clusters of every minority class example. In each iteration, AHC merges the closest pair of clusters by satisfying some similarity criteria to maintain the synthetic instances within the boundaries of a given class. The process is repeated until all the data are in one cluster. Clusters with different sizes in the tree can be valuable for discovery.

IV. Classification Techniques

In this section, a concise description of the classification algorithms used in this research is presented.

A. Random Forests

Random forest [17] is a supervised learning algorithm used for classification and regression tasks. It is distinguished from decision trees by the randomized process of finding root nodes to split features. Random forest is efficient in handling missing values. Unless a sufficient number of trees is generated to enhance prediction accuracy, the overfitting problem is a possible drawback of this algorithm.

B. Support Vector Machines

SVM is a learning algorithm used in regression tasks. However, SVM [18] is preferable in classification tasks. This algorithm is based on the following idea: if a classifier is effective in separating convergent non-linearly separable data points, then it should perform well on dispersed ones. SVM finds the best separating line that maximizes the distance between the hyperplanes of decision boundaries.

C. Artificial Neural Networks

ANN is an approximation of some unknown function and is performed by having layers of "neurons" work on one another's outputs. Neurons from a layer close to the output use the sum of the answers from those of the previous layers. Neurons are usually functions whose outputs do not linearly depend on their inputs. ANN [19] uses initial random weights to determine the attention provided to specific neurons. These weights are iteratively adjusted in the back-propagation algorithm to reach a good approximation of the desired output.

D. Naive Bayes

Naive Bayes [20] is a direct and powerful classifier that uses the Bayes theorem. It predicts the probability that a given record or data point belongs to a particular class. The class with the highest probability is considered to be the most likely class. This algorithm assumes that all features are independent and unrelated. The Naive Bayes model is simple and easy to build and particularly useful for large data sets. This model is known to outperform even highly sophisticated classification methods.

E. K-Nearest Neighbor

The KNN learning algorithm is a simple classification algorithm that works on the basis of the smallest distance from the query instance to the training sample [21] to determine the simple majority of KNN as a prediction of the query. KNN is used due to its predictive power and low calculation time, and it usually produces highly competitive results.

V. Visualization Methods

Data visualization exerts considerable impact on user software experience. The decision-making process benefits from the details obtained from large data volumes [22], which are usually built in a coherent and compact manner.

The purpose of the established model is to emphasize the importance of data visualization methods. It helps in conducting a perceptual analysis of a given situation. Visualization methods are used to illustrate hidden patterns inside data sets. This section introduces the characteristics of the visualization methods used in this research.

A. Scatter Plot

Scatter plots are a graphical display of data dispersion in Cartesian coordinates [22] that shows the strength of relationships between variables and determines their outliers. Variations include scatter plots with trend line. It is used to reveal the patterns in the normal distribution of the data points.

B. Bar Charts

Bar charts are used to represent discrete single data series [23]. The length usually represents corresponding values. Variations include multi-bar charts, floating bar charts, and candlestick charts.

C. Pie Charts

A synonym of a circle graph [23] is divided into a number of sectors to describe the size of a data wedge. Sectors are compared by using a labeled percentage. Variations include doughnut, exploding, and multi-level pie charts for hierarchical data.

D. Line Charts

Line charts visualization technique [23] is used to display the trend of data as connected points on a straight line over a specific interval of time. Variations include step and symbolic line charts, vertical–horizontal segments, and curve line charts.

VI. DataSet and Methodology

A. DataSet

The data set is obtained from the UCI machine learning repository. This data set is related to the direct marketing campaigns of a Portuguese banking institution. The current research uses the small version of the raw data set, which contains 4521 instances and 17 features (16 features and output). The classification goal is to predict whether the client will subscribe (yes/no) to a term deposit (variable y). Table I shows the dataset description, and Fig. 1 illustrates the distribution of each feature.

Fig. 2 shows the relationship between each attribute and the output. The attribute with unique values (distribution) of less than 6 is selected.

TABLE I. Attribute Information

Attribute	Description	Unique Values
age	Age	67
job	Type of job	12
marital	Marital status	3
education	Education	4
default	Has credit in default	2
balance	Credit balance	2353
housing	Has housing loan	2
loan	Has personal loan?	2
contact	Contact communication type	3
day	Last contact day of the week	31
month	Last contact month of Year	12
duration	Last contact duration, in seconds	875
campaign	Number of contacts performed during this campaign and for this client	32
pdays	Number of days that passed by after the client was last contacted from a previous campaign	292
previous	Number of contacts performed before this campaign and for this client	24
poutcome	Outcome of the previous marketing campaign	4
out	has the client subscribed a term deposit	2

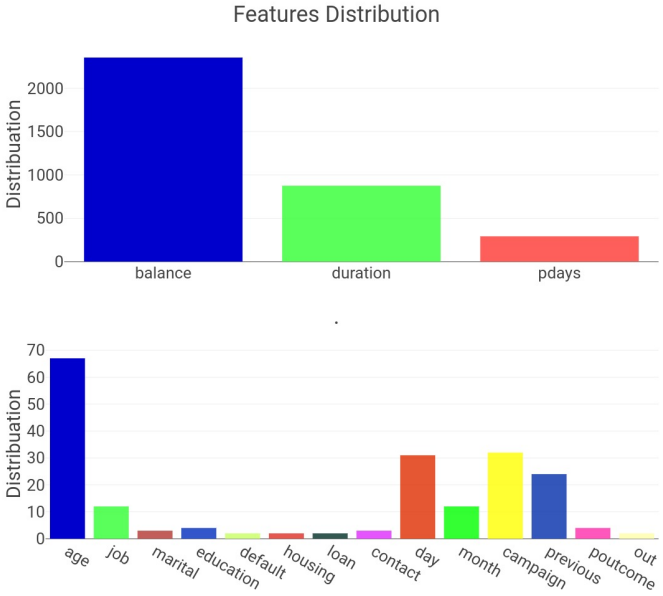

Fig. 1. Features Distribution

Fig. 2 shows the relationship between each attribute and the output. The attribute that has unique values (distribution) less than 6 is selected.

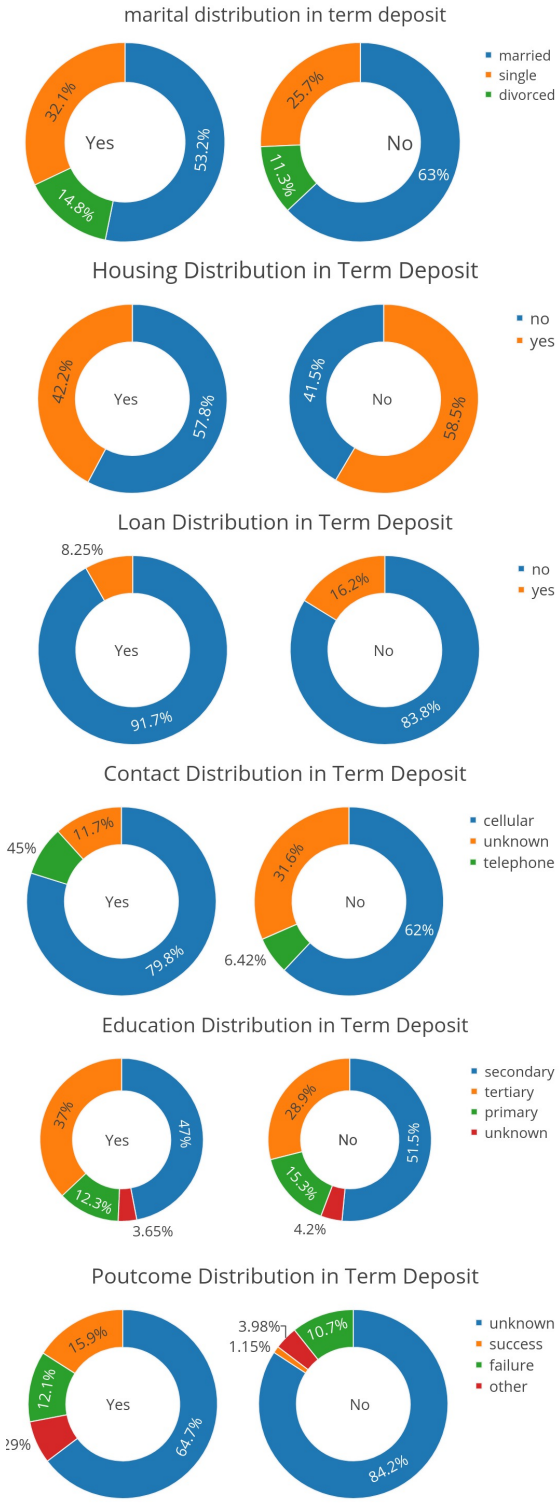

Fig. 2. Pie Chart Visualization Method for Features Distribution

According to the distribution of the target class shown in Fig. 3 and 4, the data set is imbalanced. That is, the percentage of class yes is 11.5 (500 records out of 4521), whereas that of class no is 88.5 (4021 records out of 4521).

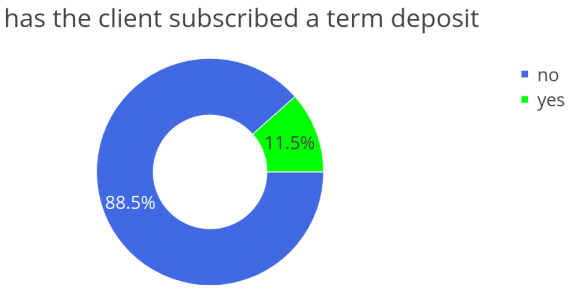

Fig. 3. Pie Chart Visualization Method for Output Distribution

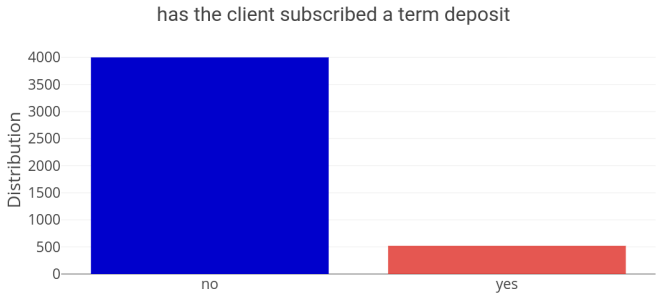

Fig. 4. Bar Chart Visualization Method for Output Distribution

B. Methodology

A preprocessing phase is first implemented to balance the data distribution by applying oversampling techniques, such as SMOTE with varying percentages. The next step is to determine which among ADASYN, ROS, SPIDER, ADOMS, and AHC is superior. The selection is aided by proper visualization methods. Then, random forest, SVM, ANN, Naive Bayes, and KNN classification algorithms are applied, and their assessment is conducted using Gmean as an evaluation metric. Other essential measurements, such as accuracy and recall, are also used.

VII. Results and Discussion

In the preprocessing step, the SMOTE percentage is set to 100. Gmean and accuracy are calculated for different classifiers. Table II shows the results.

Accordingly, the Naive Bayes technique has the highest Gmean among all techniques. The accuracy and Gmeans of all five classifiers in the original dataset are shown in Table III.

Then, Naive Bayes with different SMOTE percentages is applied to select the most appropriate one that throws the best results from this data set. Table IV shows the results of Naive Bayes on the data set with different SMOTE percentages ranging from 100 to 800.

TABLE II. Gmean and Accuracy of Different Classification Techniques after using SMOTE Oversmpling Technique with Percentage 100

Method	Gmean	Accuracy
Random forest	0.620	89.98
SVM	0.658	89.38
NN	0.667	87.635
naive bayes	0.710	85.11
K nearest neighbor	0.547	85.02

TABLE III. Results of Different Classification Techniques on the Original Dataset (Gmean,Accuracy)

Method	Gmean	Accuracy
Random forest	0.52	90.02
SVM	0.61	89.29
NN	0.59	88.18
Naive Bayes	0.68	86.88
K nearest neighbor	0.49	86.5

The best results with Naive Bayes are those with a SMOTE value set to 400, as shown in Fig. 5. The figure also shows the Gmeans of different SMOTE percentages using the Naive Bayes classifier. The results in Table IV are shown as a chart to present a clear reading of the best Gmean.

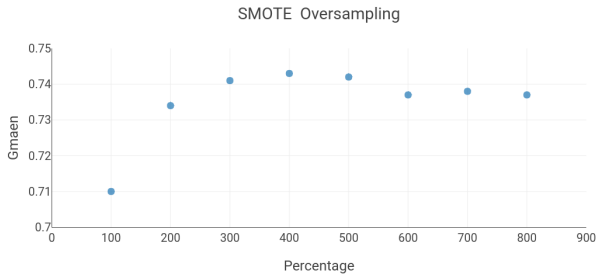

Fig. 5. Gmean of Naive Bayes with Different SMOTE Percentages Ranging from 100 to 800

Another experiment is conducted to determine the second best classifier under SMOTE set to 400. Table V shows the results. As shown in Fig. 6, the best classifier is the one with the highest Gmean, that is, Naive Bayes and SVM with a Gmean value of 0.74.

SVM and Naive Bayes are good candidates for further analysis. Naive Bayes is preferred over SVM because it is fast and easy to install. Fig. 6 shows the Gmean value before and after applying SMOTE. SMOTE enhances the Gmeans for all applied classification techniques.

The final step is to compare oversampling techniques with

TABLE IV. Gmean and Accuracy of Naive Bayes with Different SMOTE Percentages Ranging from 100 to 800

Percentage	Gmean	Accuracy
100	0.710	85.11
200	0.734	84.03
300	0.741	82.48
400	0.743	80.8
500	0.742	79.51
600	0.737	78.23
700	0.738	77.17
800	0.737	75.98

TABLE V. ACCURACY AND GMEAN OF DIFFERENT TECHNIQUES USING SMOTE WITH PERCENTAGE 400

Method	Gmean	Accuracy
Random forest	0.64	88.8
SVM	0.74	87.25
NN	0.69	86.92
naive bayes	0.74	80.80
K nearest neighbor	0.58	83.98

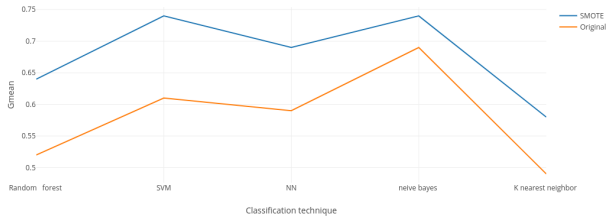

Fig. 6. Gmean of different techniques using SMOTE with percentage 400 compared with original

the best SMOTE percentage. Comparing these results with those of the original dataset is also important. Naive Bayes is used with all oversampling techniques. Accuracy and Gmean are calculated by different percentages of SMOTE. Table VI shows the results.

The scatter plot method is used to visualize the results of the six oversampling techniques, as illustrated in Fig. 7.

TABLE VI. COMPARISON BETWEEN DIFFERENT OVERSAMPLING TECHNIQUES (PERCENTAGES RANGING FROM 100 TO 800)

	Gmean					
	SMOTE	ADASYN	ROS	ADOMS	SPIDER	AHC
100	0.71	0.680	0.68	0.68	0.59	0.67
200	0.73	0.690	0.68	0.68	0.61	0.78
300	0.741	0.741	0.69	0.70	0.68	0.78
400	0.743	0.740	0.68	0.70	0.71	0.78
500	0.742	0.720	0.68	0.71	0.72	0.79
600	0.737	0.682	0.69	0.72	0.72	0.79
700	0.738	0.651	0.68	0.72	0.72	0.732
800	0.737	0.671	0.68	0.67	0.60	0.72
	Accuracy					
	SMOTE	ADASYN	ROS	ADOMS	SPIDER	AHC
100	85.11	81.43	80.90	84.83	82.51	84.43
200	84.03	78.07	79.81	83.12	82.45	84.43
300	82.48	77.28	77.03	81.89	79.13	83.71
400	80.8	74.22	76.88	81.80	80.12	82.27
500	79.51	68.52	77.08	80.11	79.15	80.96
600	78.23	66.88	76.81	80.20	78.22	77.18
700	77.17	66.23	76.90	80.27	80.11	77.63
800	75.98	66.00	76.97	80.21	79.15	76.15

Table VII shows the best percentage for all used oversampling techniques. Apart from the Gmean and accuracy of the best percentage of each oversampling technique used, Fig. 8 shows the final results. Oversampling techniques are found to enhance performance. AHC with Naive Bayes has the best Gmean among all the oversampling techniques.

VIII. CONCLUSION

This research aimed to provide a visualization mechanism for simple classification tasks. Experiments were conducted on an imbalanced data set for a direct marketing campaign of a

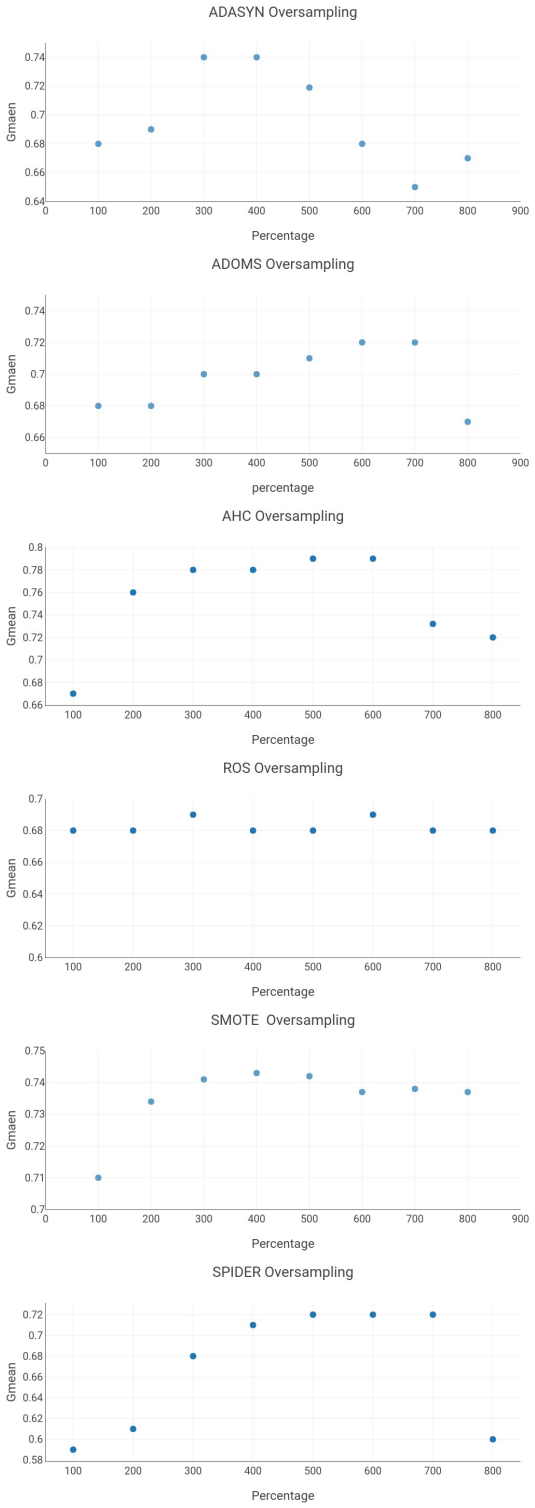

Fig. 7. Gmean of Different Oversampling Techniques with Different Percentages Ranging from 100 to 400

TABLE VII. COMPARISON BETWEEN DIFFERENT OVERSAMPLING TECHNIQUES WITH BEST GMEAN PERCENTAGE

Technique	Best Percentage	Naive Bayes Gmean	Naive Bayes Accuracy
SMOTE	400	0.743	80.8
ADASYN	300	0.741	77.278
ROS	300	0.69	77.030
ADOMS	700	0.72	80.272
SPIDER	700	0.72	80.110
AHC	500	0.79	80.960

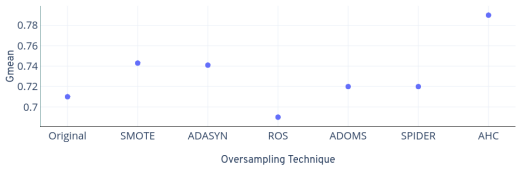

Fig. 8. Gmean of Different Oversampling Techniques Compared with Original

Portuguese bank institution. The goal was to predict whether a customer will subscribe to a term deposit. The experiments were conducted using different oversampling techniques, along with five selected common classifiers from the literature. The results showed that AHC with SMOTE of 500 outperformed the other oversampling techniques. The Naive Bayes and SVM classifiers provided the best prediction accuracy and Gmean values. Naive Bayes was preferred for its simplicity and maintainability. This research is limited to the applying of the most used oversampling techniques and it only performed on the small version of the direct marketing campaign of a Portuguese banking institution. Also, not all known classifiers involved in conducting the experiments, nor the visualization techniques and the results can be further analyzed by other performance measurements to draw more precise conclusions.

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Evaluation of Peer Robot Communications using CryptoROS

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***Abstract*—The demand of cloud robotics makes data encryption essential for peer robot communications. Certain types of data such as odometry, action controller and perception data need to be secured to prevent attacks. However, the introduction of data encryption caused increment of overhead for data stream communication. This paper presents an evaluation of CryptoROS architecture on Robot Operating System (ROS) which focused on peer-to-peer conversations between nodes with confidentiality and integrity violation. OpenSSL is used to create a private key and generate a Certificate Signing Request (CSR) that contains public key and a signature. The CSR is submitted to a Certificate Authority (CA) to chain the root CA certificate and encryption of RSA private key with AES-256 and a passphrase. The protected private key are securely backed up, transported, and stored. Experiments were carried out multiple times with and without the proposed protocol intervention to assess the performance impact of the Manager. The results for different number of messages transmitted each time increased from 100, 250 to 500 with performance impact 1.7%, 0.5% and 0.2%, respectively. It is concluded that CryptoROS capable of protecting messages and service requests from unauthorized intentional alteration with authenticity verification in all components.**

***Keywords*—Robot communication; encryption; robot operating system**

I. Introduction

In robot applications, robot sensors collect huge amount of data from the environment to characterize the situation. Certain types of data require encryption due to prevent attacks such as odometry, action controller and perception data. There are various types of data such as strings, images and point cloud data [1], [2], [3]. Robotic Operating System (ROS) provides a reliable platform for robot application but is vulnerable to cyber-attacks. It needs to be embedded with security function before obots using ROS platform reach mass market. Despite the clear advantages of robot intergration in ROS, it lacks any security protection, which makes robots insecure and prone to malicious attacks especially in robot communications [4], [5], [6].

With the demand of cloud robotics in connecting multiple robots, the encryption of data communication over the network is essential. At current state, a node in ROS can freely publish messages to a random/chosen topic without prior authorization. It can freely and without prior authorization subscribe to the topic and receive all the messages. A node can freely publish large number of messages, preventing the subscriber of this topic from carrying out meaningful information processing and causing a denial of service [7], [8]. The topic transport channel is not secure. It reveals messages to unauthorized persons, unable to detect unauthorized intentional or unintentional alteration of messages, and also cannot prove that the involved parties [9]. Therefore, there is a need to provide a total solution to overcome these situations.

Previous researches introduced various encryption solutions for robot communication [10], [11], [12], [13]. However, it was reported that the introduction of encryption caused increment of overhead for data stream communication. There were significant increments of CPU utilization and the initialization of the $ROSTOPIC$ which shown peak usage, which was the same as during attack [14]. The variety of message types in ROS play important roles as huge data stream such as images and 3D laser data. The increment of packet size causing huge delay which affected overall performance. Measurement of performances were measured based on; i) overhead for the initial handshake, ii) pure transportation overhead and iii) overhead in a normal application [15]. Therefore, this paper aims to evaluate basic performance of CryptoROS architecture as proposed in [16] with a specific data type.

The rest of this paper is organised as follows: Section II addresses related works to data encryption for robot communications. Section III explains the overall structure of CryptoROS. The experimental setup, results and discussion are presented in Section IV. This paper is concluded in Section V.

II. Related Works

Secure communication channel could be achieved by enabling ROS-nodes to communicate with authenticity and confidentiality. Rodriguez et al. [11] figured out that an increment of overhead caused by the secure channel is only a small fraction of the load application itself generates. Further investigation was conducted on a robot's performance when ciphering the messages interchanged between ROS nodes under the publish/subscribe paradigm. Some other researchers showed that AES produced superior solution in implementation and required less CPU than other encryption algorithms [17], [18]. However, it is not recommended to imply a large data overhead in the network for multi-robot environments which required continuous interaction between each components. Morante et al. [12] discovered that, in humanoid robotics, a 1% overhead while respecting determinism in time can be acceptable if it means the devices can be less vulnerable to cyber attacks.

Some other encryption method were tested in securing robot communications. Amaran et al. [10] implemented a Constrained Application Protocol (CoAP) and MQ Telemetry

Transport for Sensor Nodes (MQTT-SN) which were designed for such devices. The outcome shown that MQTT-SN performs 30% faster than CoAP when transmitting the same payload [19], [20]. Rodr et al. [21] used a 3DES cyphering algorithm and performed system, evaluation in both computing and communications aspects. Experimental results showed that symmetric ciphers using private keys imposed significant delays [22], [23]. It is observed that a huge decreased of additional response time when using the secured solution for all tested robots. Mukhandi et al. [13] managed to secure robots' network communications by providing authentication and data encryption, therefore preventing man-in-the-middle and hijacking attacks.

III. CryptoROS Structure

The proposed architecture of CryptoROS has been described in Amini et al. [16]. It focused on providing peer-to-peer conversations between nodes, which capable of ensuring confidentiality and performing integrity violation check. A computation graph was set up for DoS attacks. The entities must also be scrutinized to ensure true identity. Nodes should not be allowed to publish/subscribe a topic or advertise a service without prior authorization. For evaluation of CryptoROS, three more components were added which consist of JSON Web Token, TLS and MySQL. Two machines were configured, running only the processes needed to carry out the experiments. A rudimentary attempt was also made to assess the overhead caused by CryptoROS.

A. JSON Web Token

The JSON Web Token (JWT) structure for CryptoROS is illustrated in Fig. 1. The header and payload in the form of UTF-8 byte array was encrypted using a Base64 encoding algorithm. The resulting strings were put together and fed into a hash function (SHA-256) to produce a message digest. This message was further encrypted using the private key (RSA) to create a signature. Then, the signature was encoded with a Base64 encoding algorithm and used to form the Access Token. Receiving entities that hold the associated public key (Managers) were able to reverse the procedure in order to ensure the Access Token has been issued by a trusted party (Authorization Server).

Nodes exchange a ROS connection header when establishing new connections. The ROS connection header holds crucial information regarding the connection that was established and used to route the connection. It was connected to ROS Publisher if the ROS connection header carries the topic field, or connected to ROS Service when ROS connection header carries the service field [24], [25]. The subscriber sends together with other data, its name (callerid), topic name to subscribe/connect (topic), and data type for the messages published to this topic (type). On a successful connection, the publisher replied with the fields shown in Fig. 2.

The Interceptor intercepts ROS connection header sent by its peer, extracted certain fields from it, and then compares with the values contained within the Access Token that had been sent by its peer. Then, it decided if the connection should be aborted or not. When issuing Access Tokens, users must decide how long the Access Token should last. Short-lived Access Tokens that expire after several hours or a couple of weeks are recommended. An Access Token cannot be revoked, so if it was issued with a short expiry time, the Manager is forced to refresh it frequently. However, users must select the best configuration which suit their needs.

B. TLS

To setup and run this project, OpenSSL was used to create private key and generate a Certificate Signing Request (CSR) that contains, among other data, a public key and a signature to prove ownership of the associated private key. The CSR was sent to a Certificate Authority (CA). The CA issued a certificate and gives all of the intermediate CA certificates needed to chain to the root CA certificate. The genrsa command was used to create RSA private key as shown below. The $-aes256$ option protected the private key with AES-256 and a passphrase. Henceforth, the encrypted private key can be securely backed up, transported, and stored. The last option, 2048, stated the size of the private key to create in bits. Fig. 3 and 4 show the implementation of these processes using genrsa and req commands respectively.

Eq. 1, 2, 3 and 4 show the process flow for key generation. In order to generate a CSR, the req command was used. Option $-new$ generated a new CSR by asking the user to provide the Distinguished Name (DN) field values. Value $-key$ provided the file name for OpenSSL tool to read the private key. As mentioned earlier, the CSR carried a public key and signed using the private key associated to the public key it hold. The $x509$ command was used to sign a CSR, resulting in the creation of certificate.

$$openssl\ genrsa - aes256 - out\ mng.key\ 2048 \tag{1}$$

$$openssl\ req - new - key\ mng.key\ - out\ mng.csr \tag{2}$$

$$\begin{gathered} openssl\ x509 - req - days\ 365 - in\ mng.csr \\ -textfile\ x509\ v3extensions.txt - CA\ root.crt \end{gathered} \tag{3}$$

$$-CAkey\ root.key\ -CAcreateserial\ -out\ mng.crt \tag{4}$$

The cipher suite configuration string used in this project is shown in Fig. 5. It selected the cipher suites that will be supported by the TLS server. TLSv1.2 keyword appends TLS 1.2 cipher suites to the list. As in Eq. 5, !LOW keyword permanently deletes all low strength encryption cipher suites from the list (e.g. 56-bit or 64-bit encryption algorithms). !MD5 keyword permanently deleted all cipher suites that used the obsolete and unsecure MD5 digest algorithm from the list. All cipher suites that do not checked for authentication with the involve parties (e.g. ADH and AECDH) were permanently deleted from the list using !aNULL keyword. The use of these cipher suites was strongly discouraged because they were vulnerable to a man-in-the-middle attack. !eNULL keyword permanently deleted all cipher suites that do not offer encryption from the list. !DES, !RC2, and !RC4 keywords

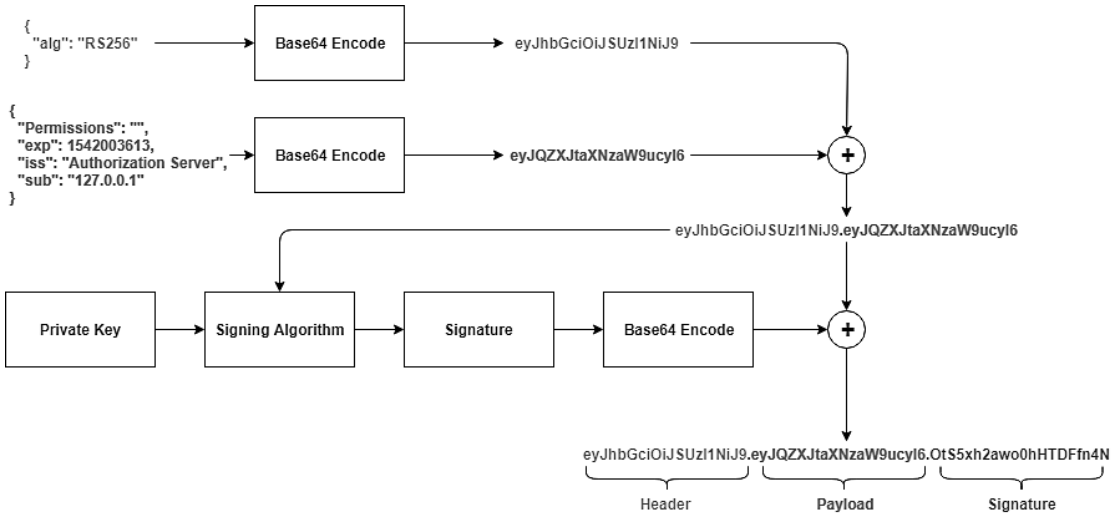

Fig. 1. JSON Web Token (JWT)

```
|.......callerid=/listener'...md5sum=992ce8a1687cec8c8bd883ec73ca41d1
...tcp_nodelay=0....topic=/chatter....type=std_msgs/String........callerid=/talker
...latching=0'...md5sum=992ce8a1687cec8c8bd883ec73ca41d1....message_definition=string data
....topic=/chatter....type=std_msgs/String
```

Fig. 2. ROS connection header. In red is the Subscriber, and in blue, the Publisher.

```
roham@roham:~$ openssl genrsa -aes256 -out egro1.key 2048
Generating RSA private key, 2048 bit long modulus
.....+++
.....................................................................+++
e is 65537 (0x10001)
Enter pass phrase for egro1.key:
Verifying - Enter pass phrase for egro1.key:
roham@roham:~$
```

Fig. 3. genrsa command

permanently deleted all cipher suites that used the obsolete and unsecure DES, RC2, and RC4 ciphers from the list, respectively. @STRENGTH keyword sorted the cipher suite list according to the cipher strength/key length [26].

$$\begin{aligned}"TLSv1.2 :! LOW :! EXPORT :! MD5 :! aNULL :\\ ! ADH :! AECDH :! DES :! eNULL : \\ ! RC2 :! RC4 : @STRENGTH" \end{aligned} \quad (5)$$

At the beginning the cipher suite list was empty, but the cipher suite list changed in some way as new keywords were added to the cipher suite configuration string. The cipher suite configuration string must be chosen carefully to avoid adding unsecure cipher suites to the list. The cipher command was invoked with the cipher suite configuration string as the parameter in order to list the cipher suites that match the requirements. As depicted in Fig. 6 the cipher suite names were very descriptive.

C. MySQL

Fig. 7 shows the Entity Relationship Diagram (ERD) for CryptoROS. The $user$ table was used to store the Manager

```
roham@roham:~$ openssl req -new -key egro1.key -out egro1.csr
Enter pass phrase for egro1.key:
You are about to be asked to enter information that will be incorporated
into your certificate request.
What you are about to enter is what is called a Distinguished Name or a DN.
There are quite a few fields but you can leave some blank
For some fields there will be a default value,
If you enter '.', the field will be left blank.
-----
Country Name (2 letter code) [AU]:MY
State or Province Name (full name) [Some-State]:.
Locality Name (eg, city) []:.
Organization Name (eg, company) [Internet Widgits Pty Ltd]:.
Organizational Unit Name (eg, section) []:.
Common Name (e.g. server FQDN or YOUR name) []:192.168.0.133
Email Address []:.

Please enter the following 'extra' attributes
to be sent with your certificate request
A challenge password []:
An optional company name []:
roham@roham:~$ openssl req -text -in egro1.csr -noout
Certificate Request:
    Data:
        Version: 0 (0x0)
        Subject: C=MY, CN=192.168.0.133
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (2048 bit)
                Modulus:
                    00:a5:35:9f:a1:89:4c:e0:68:e2:9a:83:e8:c2:de:
                    62:2c:5d:3d:21:c9:98:b0:f7:2b:38:b2:a0:fb:87:
                    90:0b:be:c9:b3:68:46:79:1d:a3:a1:f5:a4:20:38:
                    6c:d5:96:bb:53:10:f3:7d:fb:f0:cf:35:0d:a8:81:
                    0f:3c:85:da:7c:7a:2e:e1:e8:62:39:84:14:30:44:
                    41:21:2f:ce:bb:b8:1e:65:13:35:a1:87:21:0b:2f:
                    09:09:32:b5:71:3a:3f:0b:20:e7:be:e3:c8:ff:4a:
                    cc:38:e1:8e:5d:ce:4d:2f:32:2c:39:b7:78:23:25:
                    34:73:54:3a:51:a9:55:b6:8e:12:f3:d9:dd:aa:12:
                    de:45:e1:01:d1:94:ef:59:9e:7d:af:c9:c9:91:c2:
                    98:8f:68:2a:0e:4a:a0:d3:2d:2d:cc:e3:49:cc:df:
                    a0:09:fe:a5:db:eb:d3:7f:28:ca:76:47:77:4e:ef:
                    a5:8c:b9:07:3f:9e:ed:62:fa:a3:57:79:10:10:80:
```

Fig. 4. req command

credentials. A Manager managed several publishers. This relationship was represented by a one-to-many relationship between the $user$ table and the $publisher$ table. The columns named $name$, $topic$, and $data\_type$ stored the name of the node, the (name of the) topic to publish messages to, and the data type of the messages published to this topic, respectively. The same applied to the subscribers, services, and service clients.

```
rohan@rohan:~$ openssl ciphers -v 'TLSv1.2:!LOW:!EXPORT:!MD5:!aNULL:!ADH:!AECDH:!DES:!eNULL:!RC2:!RC4:@STRENGTH'
ECDHE-RSA-AES256-GCM-SHA384 TLSv1.2 Kx=ECDH     Au=RSA  Enc=AESGCM(256) Mac=AEAD
ECDHE-ECDSA-AES256-GCM-SHA384 TLSv1.2 Kx=ECDH     Au=ECDSA Enc=AESGCM(256) Mac=AEAD
ECDHE-RSA-AES256-SHA384 TLSv1.2 Kx=ECDH     Au=RSA  Enc=AES(256)  Mac=SHA384
ECDHE-ECDSA-AES256-SHA384 TLSv1.2 Kx=ECDH     Au=ECDSA Enc=AES(256)  Mac=SHA384
DH-DSS-AES256-GCM-SHA384 TLSv1.2 Kx=DH/DSS   Au=DH   Enc=AESGCM(256) Mac=AEAD
DHE-DSS-AES256-GCM-SHA384 TLSv1.2 Kx=DH       Au=DSS  Enc=AESGCM(256) Mac=AEAD
DH-RSA-AES256-GCM-SHA384 TLSv1.2 Kx=DH/RSA   Au=DH   Enc=AESGCM(256) Mac=AEAD
DHE-RSA-AES256-GCM-SHA384 TLSv1.2 Kx=DH       Au=RSA  Enc=AESGCM(256) Mac=AEAD
DHE-RSA-AES256-SHA256   TLSv1.2 Kx=DH       Au=RSA  Enc=AES(256)  Mac=SHA256
DHE-DSS-AES256-SHA256   TLSv1.2 Kx=DH       Au=DSS  Enc=AES(256)  Mac=SHA256
DH-RSA-AES256-SHA256    TLSv1.2 Kx=DH/RSA   Au=DH   Enc=AES(256)  Mac=SHA256
DH-DSS-AES256-SHA256    TLSv1.2 Kx=DH/DSS   Au=DH   Enc=AES(256)  Mac=SHA256
ECDH-RSA-AES256-GCM-SHA384 TLSv1.2 Kx=ECDH/RSA Au=ECDH Enc=AESGCM(256) Mac=AEAD
ECDH-ECDSA-AES256-GCM-SHA384 TLSv1.2 Kx=ECDH/ECDSA Au=ECDH Enc=AESGCM(256) Mac=AEAD
ECDH-RSA-AES256-SHA384  TLSv1.2 Kx=ECDH/RSA Au=ECDH Enc=AES(256)  Mac=SHA384
ECDH-ECDSA-AES256-SHA384 TLSv1.2 Kx=ECDH/ECDSA Au=ECDH Enc=AES(256)  Mac=SHA384
AES256-GCM-SHA384       TLSv1.2 Kx=RSA      Au=RSA  Enc=AESGCM(256) Mac=AEAD
AES256-SHA256           TLSv1.2 Kx=RSA      Au=RSA  Enc=AES(256)  Mac=SHA256
ECDHE-RSA-AES128-GCM-SHA256 TLSv1.2 Kx=ECDH     Au=RSA  Enc=AESGCM(128) Mac=AEAD
ECDHE-ECDSA-AES128-GCM-SHA256 TLSv1.2 Kx=ECDH     Au=ECDSA Enc=AESGCM(128) Mac=AEAD
ECDHE-RSA-AES128-SHA256 TLSv1.2 Kx=ECDH     Au=RSA  Enc=AES(128)  Mac=SHA256
ECDHE-ECDSA-AES128-SHA256 TLSv1.2 Kx=ECDH     Au=ECDSA Enc=AES(128)  Mac=SHA256
DH-DSS-AES128-GCM-SHA256 TLSv1.2 Kx=DH/DSS   Au=DH   Enc=AESGCM(128) Mac=AEAD
DHE-DSS-AES128-GCM-SHA256 TLSv1.2 Kx=DH       Au=DSS  Enc=AESGCM(128) Mac=AEAD
DH-RSA-AES128-GCM-SHA256 TLSv1.2 Kx=DH/RSA   Au=DH   Enc=AESGCM(128) Mac=AEAD
DHE-RSA-AES128-GCM-SHA256 TLSv1.2 Kx=DH       Au=RSA  Enc=AESGCM(128) Mac=AEAD
DHE-RSA-AES128-SHA256   TLSv1.2 Kx=DH       Au=RSA  Enc=AES(128)  Mac=SHA256
DHE-DSS-AES128-SHA256   TLSv1.2 Kx=DH       Au=DSS  Enc=AES(128)  Mac=SHA256
DH-RSA-AES128-SHA256    TLSv1.2 Kx=DH/RSA   Au=DH   Enc=AES(128)  Mac=SHA256
DH-DSS-AES128-SHA256    TLSv1.2 Kx=DH/DSS   Au=DH   Enc=AES(128)  Mac=SHA256
ECDH-RSA-AES128-GCM-SHA256 TLSv1.2 Kx=ECDH/RSA Au=ECDH Enc=AESGCM(128) Mac=AEAD
ECDH-ECDSA-AES128-GCM-SHA256 TLSv1.2 Kx=ECDH/ECDSA Au=ECDH Enc=AESGCM(128) Mac=AEAD
ECDH-RSA-AES128-SHA256  TLSv1.2 Kx=ECDH/RSA Au=ECDH Enc=AES(128)  Mac=SHA256
ECDH-ECDSA-AES128-SHA256 TLSv1.2 Kx=ECDH/ECDSA Au=ECDH Enc=AES(128)  Mac=SHA256
AES128-GCM-SHA256       TLSv1.2 Kx=RSA      Au=RSA  Enc=AESGCM(128) Mac=AEAD
AES128-SHA256           TLSv1.2 Kx=RSA      Au=RSA  Enc=AES(128)  Mac=SHA256
rohan@rohan:~$
```

Fig. 5. Cipher suite configuration string

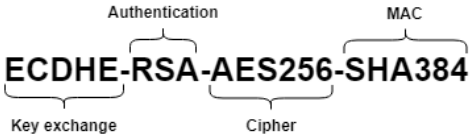

Fig. 6. Cipher suite name

IV. Results and Discussions

A. Experimental Setting

The purpose of this paper is to demonstrate how the proposed solution can alleviate the impact of various strategies used by malicious actors in order to exploit ROS based robots. The following experiments were carried out to analyze the performance impact of the Manager. All tests were executed on environment configurations consist of hardware, software, and network as listed in Table I.

In this experiment, a publisher named *talker* was advertised its intention of publishing messages to a topic named *chatter*. A subscriber named *listener* subscribed to topic *chatter*. Given the publisher's XML-RPC URI, the subscriber initiated, negotiated and established topic specific connection. The publisher began transmitting one hundred messages of type *std_msgs/String* afterwards, as shown in Fig. 8. The time command was used to launch the subscriber. When the program finished, time elapsed since its invocation was written to standard error by the time command [27]. The experiments were carried out 3 times with and without the proposed protocol intervention and the number of messages transmitted each time increased from 100, 250 and 500.

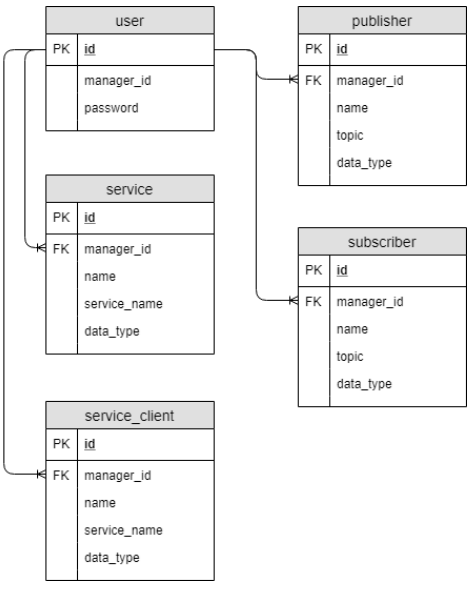

Fig. 7. Entity Relationship Diagram (ERD)

TABLE I. Evaluation Machine

CPU	Machine 1	Machine 2
Processor Number	Intel Core i5-6300HQ	Intel Core i5-3230M
Cores	4	2
Threads	4	4
Frequency	2.30 GHz - 3.20 GHz	2.60 GHz - 3.20 GHz
Memory (RAM)	8.00 GB	8.00 GB
Network	30 Mbps	30 Mbps

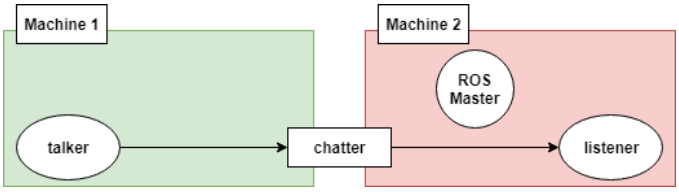

Fig. 8. Experimental setup

As mentioned previously, an attendee well versed in ROS was capable of controlling the ROS based robot without using the provided web based user interface during the DEF CON 20 conference [28]. These attacks required to a certain extent with little effort to accomplish. In the absence of the proposed protocol, data was transmitted in plain text format as depicted in Fig. 9. A TLS session was negotiated and established in accordance with the proposed protocol in order to secure the conversation as shown in Fig. 10.

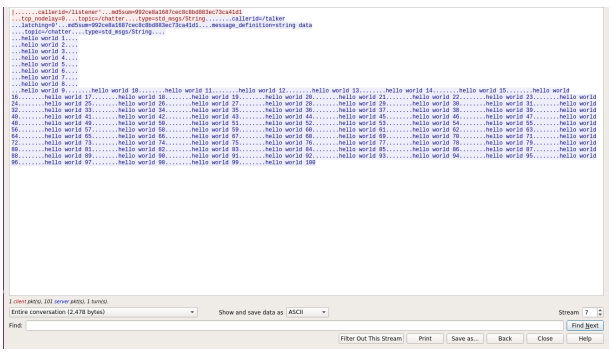

Fig. 9. Unencrypted data captured by Wireshark

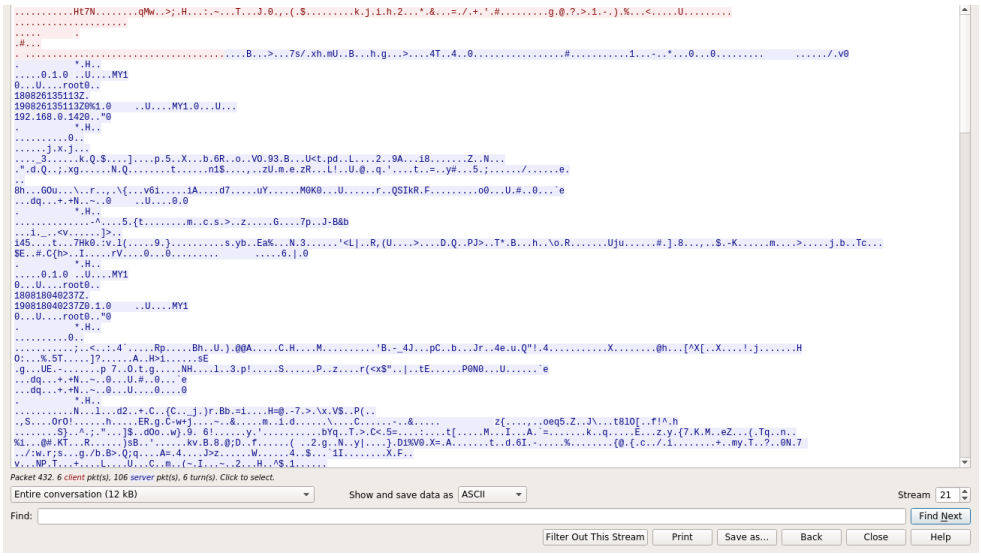

Fig. 10. Encrypted data captured by Wireshark

B. Performance Impact

The time elapsed values (Fig. 11, 12, 13) were obtained from launching the subscriber using the time command with and without the proposed protocol intervention. The summary of results in Table II concluded that the performance impact was inconsequential. To reduce the performance impact caused by the proposed protocol, the implementations were conducted using rich feature set offered by modern C++ (C++11 and C++14 standards). The finite computing resources used by class objects were also gracefully released (e.g. closing sockets) when appropriate to avoid running out of these resources. However, the size of the transferred data has increased from 2,478 bytes to 14,478 bytes. It happened based on the following factors; 1) many handshake messages required full handshake to negotiate and established a TLS session and 2) JWT was used for secure information transmission between the involved entities (e.g. publisher, subscriber).

The implementation of CryptoROS was capable in preventing unauthorized publishing and subscribing. The TLS handshake for inbound and outbound of peer-to-peer connection will failed and prohibit malicious nodes which were not supposed to be part of a specific conversation from injecting data. The attack surface for denial of service in ROS has also been decreased. The Interceptors could be configured to drop XML-RPC shutdown requests, preventing attackers from shutting down nodes. This approach also made sure the messages, service requests and responses were not be disclosed to unauthorized persons (confidentiality). Any unauthorised intentional or accidental alteration of them was detected (integrity) and the proposed protocol ensured the authentication of involved entities.

TABLE II. AVERAGE ELAPSED TIME (S)

No. Messages	Without CryptoROS	With CryptoROS	Performance Impact
100	10.534	10.711	1.7%
250	25.588	25.713	0.5%
500	50.628	50.747	0.2%

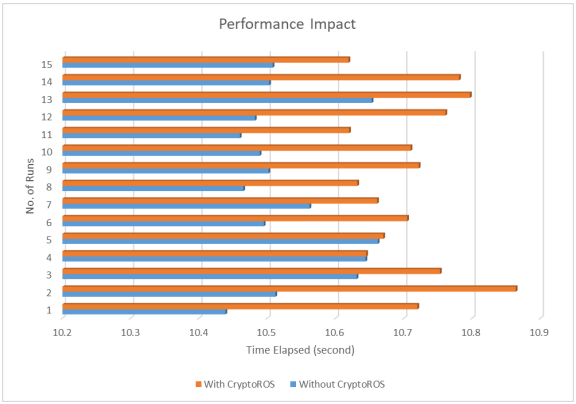

Fig. 11. Performance impact for 100 messages

V. CONCLUSION

CryptoROS has been designed in such a way that no changes needed to ROS software libraries and tools. Additionally, rebuilding nodes were not required to occupy secure conversation channels. CryptoROS works with all ROS client libraries regardless of the programming language they have been implemented. It can be concluded that CryptoROS does not increase much in computation time while providing security for peer robot communications. Further study should focused on evaluation in various types of data such as point cloud data and images.

ACKNOWLEDGMENT

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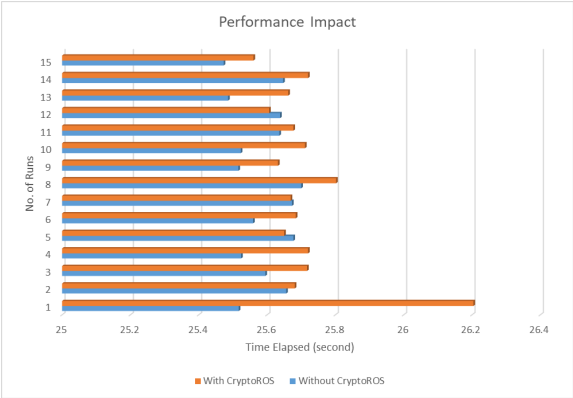

Fig. 12. Performance impact for 250 messages

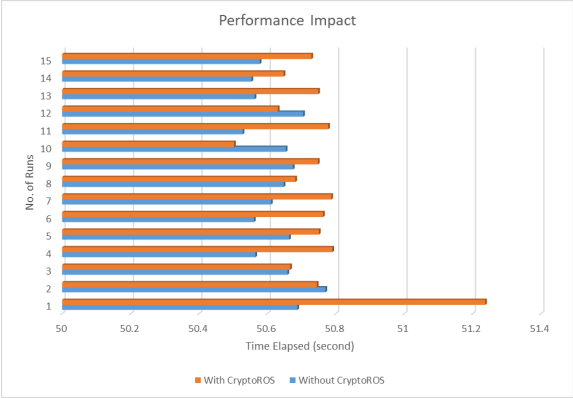

Fig. 13. Performance impact for 500 messages

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A Novel Image Encryption using Memetic Differential Expansion based Modified Logistic Chaotic Map

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***Abstract*—Under this paper, the primary conditions of a modified logistic chaotic map are created with the help of memetic differential expansion. In the beginning, the color image is broken down into different channels like red, blue and green. Then the modified logistic chaotic map essential variables are enhanced with the execution of memetic differential expansion. The strength operation is employed by the association coefficient and Entropy function. The private keys are produced by the modified logistic chaotic map. The encoded image is acquired with a combination of different encoded color channels. The memetic differential expansion builds on image encryption and the previous image encryption techniques build with the different standard images play a vital role in carrying out the larger experiments. The evaluation of the outcome of the proposed technique gives better security and efficiency in contrast to all the previously implemented image encryption techniques.**

Keywords*—Image encryption; modified logistic chaotic map; memetic differential expansion

I. Introduction

The reliability of contents which is available on the digital platform is becoming the most exigent point with the development of many software applications and latest technologies [1]. In several operations like military, remote sensing, imaging in medical, etc. images plays the major part [2].

Hongjun et al. implement the stream-encoded approach that consists of single way keys and vigorous chaotic maps. This approach ensures a high level of security and upgraded the active breakdown. The piecing chaotic map is used to create the artificial random key stream series [3].

Yaobin et al. implement the image encryption scheme based on the baker map in three dimensional that results in high security with speedy image encryption technique [4], [5].

To have preferable image encryption outcomes, Chaotic maps are considerably used [6]. Usama et al. utilized several chaotic maps. Some of them are Sine, Tent, Logistic, Cubic, etc. to encode the images [7].

Guodong et al. proposed an encryption technique with the help of Arnold map that consists of two divisions, i.e., arrangement and distribution. Initially, an entire circular operation is utilized in the arrangement division that considerably minimizes the association linking the adjoining pixels. Afterward, at the distribution stage dual diffusion operations that include constructive and contradictory module are used along with novel production of keystream [8], [9].

Ruisong et al. proposed an approach of image encryption that has inbuilt features of arrangement and distribution technique. Initially, for the arrangement of image pixel place, an un-specialized Arnold map in the arrangement phase is used to create a single chaotic path to receive dual index sequences. While in the distribution phase, un-specialized Arnold map along with un-specialized Bernoulli fetch map are engaged to capitulate dual imitation random gray points order for a dual-process distribution of gray points [10], [11].

Kwok et al. implement the high potential propagation technique that uses elementary list lookup along with exchange approach as a thin-mass substitute of one-dimensional chaotic map repetition [12].

Chong et al. proposed an approach that is built on a bit size arrangement technique to have reliable and well-organized image encryption. This approach launch the remarkable diffusion consequences in the arrangement process along with dual division bit-size jumble algorithm that perceives by both chaotic order organized algorithm and Arnold cat map [13].
Yong et al. implement the quick image cipher technique which is the combination of arrangement and distribution algorithm. In this approach, the initial image is broken down into the number of pixels. Afterward, fourth dimension chaos is used to rearrange the pieces and also to alter the pixel worth [14].

Fabian et al. implement a method to encode-decode the color effective occurrence with the help of the original optical substitute. Then the three fundamental chromatic medium which creates the initial parameter gets split. Afterward, the individual medium is executed with the help of 4f encryption procedure and theta moderation pertain to every encoded frame in each medium [15].

Sahar et al. implement an approach named Coupled Nonlinear Chaotic Map (CNCM) and image encryption scheme build in chaos to encode the color images with the help of the implemented approach [16], [17].

Madhusudan et al. implement the technique for color image encryption with the help of fractional Fourier transform [18].

Chong et al. proposed an improved version of the distribution plan to encourage the effectiveness of the extensively scrutinize arrangement-distribution kind image encryption [19].

Licheng et al. proposed the memetic approach which proves more powerful in contrast with the dual state of the technique image section approach that further consist of effective graph build technique and spectral group build algorithm and also defeat its hereditary type, fuzzy c-mean technique and also the k-mean approach is dividing many of the problems [20].

Kumar et al. implement the elliptic curve cryptography along with DNA to encode the images [21].

There are several image encryption approaches which are meta-heuristic in nature such as Genetic Algorithm (GA) [22], [23], [24], Many Objective Non-Dominated Sorting Genetic Algorithm build on Reinforcement learning (MNSGA-RL) [25], Ant Colony Optimization (ACO) [26], differential evolution [27] and Dynamic Harmony Search(DHS) [28]. Although these all are having bad computational speed.

Chunyan et al. proposed a modified logistic chaotic map to improve the security in the case of a single logistic map [29]. Wai et al. implement the modified chaotic cryptographic technique which executes on the logistic map. The result proves the diffusion of the encoded text compliment and to minimize the execution time [30].

So in this research Paper, modified memetic differential expansion is used for upgrading the first situation recommend by the modified logistic chaotic map. This paper implements the image encryption technique by evaluating the modified logistic chaotic map and memetic differential expansion.

Firstly, the color image is split among three different channels like red, blue and green. Then, the modified logistic chaotic map is used to create different secret keys to encode the channels. The memetic differential expansion modifies the input of the modified logistic chaotic map. Afterward, all distinct encoded channels are combined to get the final encoded image.

The rest of the portion of this paper explains the "Preliminaries" part that briefly tells about the modified logistic chaotic map and memetic differential expansion. The implemented approach of image encryption is discussed under the "Proposed Technique" section. The section "Evaluation of Performance" explores the examination of the implemented approach. The conclusion part describes in the section "Conclusion".

II. Preliminaries

This section briefly explains the modified logistic chaotic map and memetic differential expansion.

A. Modified Logistic Chaotic Map

Modified Logistic Map is represented by the expression which is given below:

$$y_{i+1} = \frac{(2\beta) - y_i^2}{\beta} \tag{1}$$

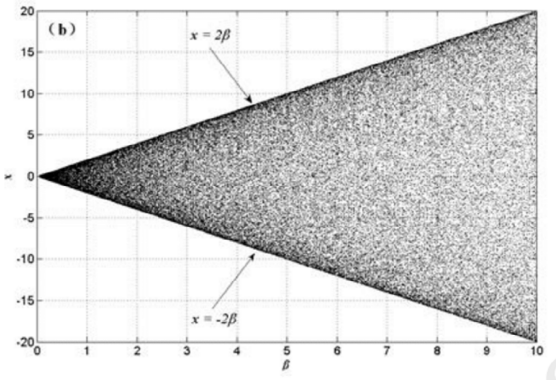

Fig. 1. Diagram for the bifurcation

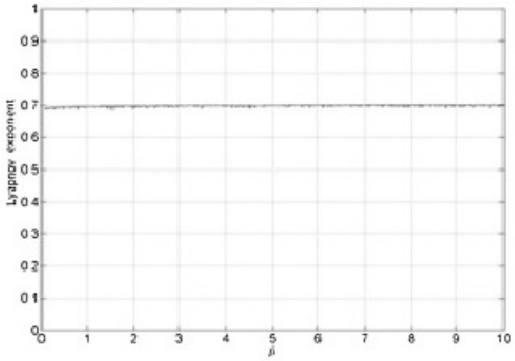

Fig. 2. Lyapunov value spectrum

β is the function and y_i is the primary value of the operation. As soon as the β value is changed in the above equation 1, the complete mapping will execute along with the occurrence of continual chaos and static Lyapunov Value with the correlating continual function where the range of the complete mapping is given by range $\in$ [-2β, 2β] [29].

Fig. 1 and Fig. 2 respectively represents the diagram of Bifurcation and Lyapunov Value Spectrum of the given equation. The essential part along with the mapping range will lead to infinity when the static chaotic indication generator builds on the modified Logistic map is put in the communication area. The Modified logistic chaotic map is used as an artificial random series generator in the area of image encryption.

B. Memetic Differential Expansion

Jia et al. in 2011 implement the memetic differential expansion which is built on confined chaotic explore [31]. There are several benefits of this technique over the normal differential expansion. The first advantage is that the functions of differential expansion such as Scaling element (E) and traverse rate (TR) which are nearly link along with convergence execution are easily managed by this technique. The stability between the Community variety and convergence rate is created by it. Another advantage is, as soon as the technique is converted into an inactive mode in community exploration, then the differential expansion becomes familiar for worldwide development. To increase the development production in community exploration

the memetic differential expansion utilizes the chaotic process. To reduce the implementation time, the purified parameters apply to the Chaotic community exploration (CCE). The steps involved in the memetic differential expansion are given below:

1) **Preparatory:** With the help of normal distribution, the primary community is created that includes the values for random responses. The strength of every response of the community is evaluated.
2) **Alteration:** Three randomly chosen response from the community is used to create alteration responses.
3) **Traverse:** The test response is implemented with the combination of estimated response and alteration response. Based on the traverse rate, the values of test responses are picked from the estimated response and alteration response.
4) **Selecting the test response:** The test response strength is generated and compare it with the estimated response. It will go for the further process only if it has better strength in test response. Else, the further process is executed by using the previous responses.
5) **Chaotic Community Exploration:** To clarify the responses, Community exploration is executed on the estimated response with the help of the chaotic process. The exploration ability of differential expansion is increased and also prevents it from the problem of untimely convergence.
6) **Ending State:** If ending state is fulfilled, the process ends. Else, it will again start executing from the Steps (ii)-(v).

III. Proposed Technique

A. Simulation

The considerable analysis of old techniques designates that most of the old image encryption approaches encounter the loss either in portable keyspace or their beginning situations may be obtained physically. The private key is responsible for the robustness of the encryption technique. Hence, it is obligatory to choose proper starting parameters because they are the reason for the generation of the private key. By stimulating all this certainty, a better encryption technique is proposed in the domain of images. Under this technique, private keys are created by the memetic differential expansion build on a modified logistic chaotic map for the encryption procedure. The encryption and decryption procedure of the implemented encryption technique is explained in the successive sections.

B. Encryption Procedure

The encryption procedure of the implemented technique is shown in Fig. 3. Firstly, a color image is divided into different mediums such as red, blue and green. The modified logistic chaotic map builds on the memetic differential expansion is used to create the private keys to encode the mediums. After that an encrypted image is created which is the result of the combination of all encoded mediums.

Step 1: Initially, a color image (M_{ic}) having j columns and h rows.

Step 2: Divide M_{ic} in among different color mediums such as red (C_r), blue (C_b) and green (C_g) .

Step 3: With the help of the modified logistic chaotic map, private keys are created i.e., q, u, and t. The values which are required by the modified logistic chaotic map is enhanced with the utilization of memetic differential expansion. The size of private keys i.e., q, u, and t is similar to the size of mediums.

Step 3.1 Strength Parameter: The strength parameter which is acquired from the memetic differential expansion is analyzed using the association coefficients and entropy. Every pixel of an encoded image has a similar chance of occurrence if the outcome of entropy is intense [32]. The encoded image should have a minimum value as possible in the case of association [33]. Hence, the major goal of memetic differential expansion is to boost the entropy and reduce the association coefficient of an encoded image.

The strength parameter (s) is evaluated as:

$$s(a_1, a_2) \tag{2}$$

where,

$$a_1 = -\sum_{n=0}^{2^m-1} (Z(p_n) \times log_2 Z(p_n)), \quad s.t. \;\; 7.9 < a_1 \tag{3}$$

and

$$a_2 = \frac{\sum_{n=1}^{T} (b_n - H(b))(d_n - H(d))}{\sqrt{\sum_{n=1}^{T}(b_n - H(b))^2}.\sqrt{\sum_{n=1}^{T}(d_n - H(d))^2}}, \tag{4}$$

where s.t. $a_2 \in$ {-1,0.5}

Entropy (a_1) and association coefficient (a_2) is represented in Eqs. (3) and (4) respectively. The appearance of pixel p_n is denoted by $Z(p_n)$. The quantity of pixel pairs (b_n, d_n) is indicated by the T . The mean of b_n and d_n is denoted by $H(b)$ and $H(d)$, respectively. The amount of gray levels is represented by m.

Step 3.2 Preparatory: The memetic differential expansion has primary responses which are explained as:

$$R_j^n = [r_{j1}^n, r_{j2}^n, \ldots, r_{j8}^n], \;\; j \in \{1, 2, \ldots, C_r\} \tag{5}$$

Here, the community size is represented by the C_r. Under the n production the k^{th} variable from j^{th} response is denoted by r_{jk}.

With the help of normal distribution, every response is created randomly in this process. 8 denotes the size of every random response (R_j^n). The end variable serves as the encryption element (η) and the private keys are generated by the initial different variables of every P_j^n which is allocated to the modified logistic chaotic map. Inside the scope of $[0, 1]$, each R_j^n choose scaling element (E) and traverse rate (TR) separately. Eq. (2) is utilized to analyze the strength parameter of an encoded image along with random responses

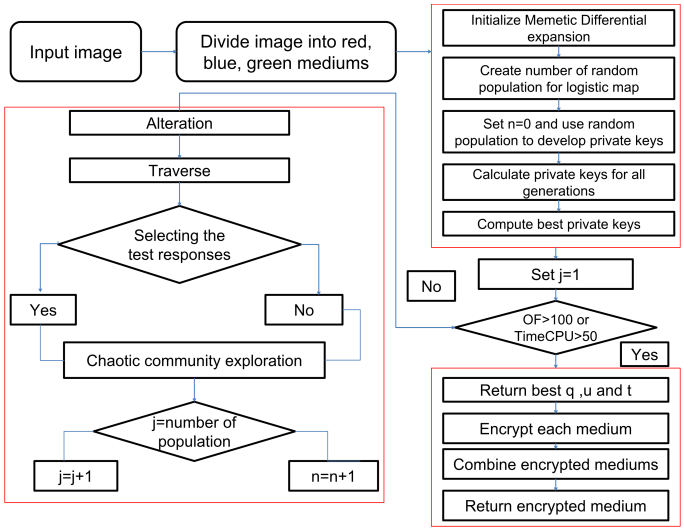

Fig. 3. Flowchart of a proposed image encryption approach

R_j^n.

Step 3.3 Alteration: By aggregating the variation of dual responses into the other one, an alteration response (A_j^n) is created by memetic differential expansion.

$$A_j^n = R_{l_3}^n + E^f \cdot (R_{l_2}^{nf} - R_{l_1}^{nf}) \\ l_1, l_2, l_3 \in \{1, 2, \ldots, C_r\}, \quad f \in \{1, 2\} \tag{6}$$

Here, Randomly picked responses against the similar community (however, $l_1 \neq l_2 \neq l_3 \neq i$) is represented by l_1, l_2, and l_3. The amount of differential response engaged in alteration procedure is denoted by f . Scaling element is represent by E and restricted to range $[0, 1]$.

Step 3.4 Traverse: The combination of alteration response (A_j^n) along with its primary response (R_j^n) is lead to the creation of test response (i.e., P_j^n). The procedure of picking the variables of P_j^n is given as:

$$p_{jk}^n = \begin{cases} a_{jk}^n, & rand(k) \leq TR, \\ r_{jk}^n, & rand(k) > TR. \end{cases} \tag{7}$$

where, Variables of P_j^n and A_j^n is represented by the p_{jk}^n and a_{jk}^n, respectively.
$k \in \{1, 2, \ldots, 8\}$ and Traverse rate is indicated by TR .

Step 3.5 Selecting the test responses: To acquire the private keys, a Modified logistic chaotic map is allocated by the variables of every P_j^n. Encrypted image C_r is created by the utilization of these private keys. The comparison is done under this procedure between the strength of the encoded image which is created through P_j^n and the previous R_j^n. Afterward, the response having the preferable strength will go for further execution.

$$R_j^{n+1} = \begin{cases} P_j^n, & \text{if } f(P_j^n) > f(R_j^n), \\ R_j^n, & \text{otherwise.} \end{cases} \tag{8}$$

Step 3.6 Chaotic community exploration: Chaotic community Exploration (CCE) is used to further clarify the acquired responses i.e., R_j^n. Evaluation of CCE is done as follows:

$$R_j^{'(n)} = (1 - \beta) R_j^n + \beta \gamma_w \tag{9}$$

CCE creates the new response of R_j^n which is denoted by $R_j^{'(n)}$. The diminishing scale is represented by β and is computed as :

$$\beta = 1 - \left| \frac{OFs - 1}{OFs} \right|^{\lambda} \tag{10}$$

where the latest operation estimation is denoted by OFs. λ is used to manage the diminishing rate. Diminishing rate is inversely dependent on the λ, i.e. if the λ is low then the value for diminishing rate is high. γ_w is calculated as given below:

$$\gamma_w = U + \gamma_k^{\nu} \cdot (V - U), \tag{11}$$

Here, the exploration space of R_j is denoted by $[U, V]$. Modified logistic Chaotic map is used to acquire the γ_k^{ν}. The steps for estimation of Modified logistic Chaotic map is given below:

$$\gamma_k^{\nu+1} = \mu \gamma_k^{\nu} (1 - \gamma_k^{\nu}), \quad \nu = 1, 2, \ldots; \quad \gamma_k \in (0, 1), \tag{12}$$

Here, $\gamma_k \neq 0.25, 0.5$, and 0.75 and under the ν^{th} creation, the k^{th} chaotic variable is represent by γ_k^{ν}. The bifurcation standard variable is denoted by μ.

Step 3.7 Ending State: To end the procedure, the dual constraints, i.e., operation estimation and CPU measure are taken into account. The operation estimation gives better appropriate outcomes if its value is at an extreme point. Although, in a few situations, the CPU takes much more time. Therefore, it is the restriction in the technique. Hence, the Ending state is implemented to end the technique which is given as follows:

$$EndingState = \begin{cases} 1, & OF > 100, \\ 1, & Time_{CPU} > 50sec, \\ 0, & otherwise. \end{cases} \tag{13}$$

where the entire evaluation time is taken by the memetic differential expansion so far is denoted by the $Time_{CPU}$.
Steps 3.3 - 3.7 are executed again only if the ending state is not fulfilled. Else, it gives the optimal variable.

Step 4: The mediums C_r', C_b', and C_g' are encrypted by using the encryption element (η) and different private keys,

i.e., q_n, u_n, and t_n (where $n = \{1, 2, \ldots, h \times j\}$) which are acquire through memetic differential expansion.

$$E_R = \mod(\eta \times C'_r + (1-\eta) \times q, p_h) \quad (14)$$

$$E_B = \mod(\eta \times C'_b + (1-\eta) \times u, p_h) \quad (15)$$

$$E_G = \mod(\eta \times C'_g + (1-\eta) \times t, p_h) \quad (16)$$

where, the encoded red, blue and green medium is denoted by E_R, E_G and E_B, respectively. The top pixel of M_{ic} is represented by p_h .

Step 5: In order to estimate the encrypted image (I_{ec}) the encoded mediums E_R, E_B, and E_G are merged all together.

$$I_{ec} = cat(E_R, E_B, E_G) \quad (17)$$

C. Decryption Procedure

The identical private keys (i.e., q, u, and t) and similar encryption element (η) are requisite in order to decrypt the encrypted image. Consequently, the receiver is required to communicate with the tuned variables.

Step 1: I_{ec} is divided among different encrypted color mediums. Red (E_R), green (E_G) and blue (E_B) are the required encrypted mediums.

Step 2: The tunned variables are used to modified logistic chaotic map in order to create the private keys, i.e., q, u, and t .

Step 3: Decryption medium is acquire as follows by applying the q, u, t, and η on every encrypted medium.

$$C'_r = (E_R - (1-\eta) \times q)/\eta \quad (18)$$

$$C'_b = (E_B - (1-\eta) \times u)/\eta \quad (19)$$

$$C'_g = (E_G - (1-\eta) \times t)/\eta \quad (20)$$

where, decrypted color mediums are denoted by C'_r, C'_b, and C'_g .

Step 4: With the combination of C_r, C_b, and C_g mediums, the required decrypted image (I_{dc}) is derived.

$$I_{dc} = cat(C_r, C_b, C_g) \quad (21)$$

IV. Evaluation of Performance

Experiments are carried out on MATLAB software, Intel Core 2.4 GHz $i7$ Processor having RAM 32 GB to estimate the usefulness of the implemented technique. With the 256 × 256 size, different standard color images are extracted [34].

The original color images are represented in Fig. 4 (a)-(e). The images which are the result of the encryption procedure of the proposed technique are designate in Fig. 4 (f)-(j). The images which are created through the decryption procedure of the implemented approach are shown in Fig. 4 (k)-(o). The image which is generated by the decryption procedure and original image are similar. Hence, the remarkable visual standard is achieved by the proposed technique.

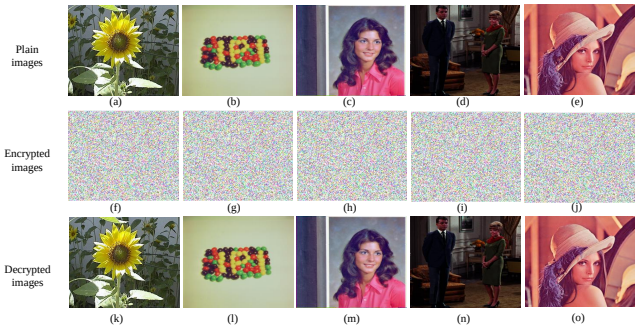

Fig. 4. Evaluation of the performance of implemented technique: (a)-(e) original images, (f)-(j) Image obtained from encryption process, and (k)-(o) Image obtained through decryption process.

TABLE I. Differentiation on the basis of entropy (in bit/pixel)

Technique	Sunflower	Beans	Female	Duplet	Lena
LW *I.E.* [39]	7.9860	7.9837	7.9864	7.9850	7.9871
NL *I.E.* [40]	7.9695	7.9765	7.9793	7.9756	7.9799
LV *I.E.* [41]	7.9765	7.9788	7.9798	7.9755	7.9807
ECB *I.E.* [38]	7.9754	7.9755	7.9775	7.9788	7.9786
SPN C *I.E.* [36]	7.9971	7.9983	7.9984	7.9988	7.9470
FMM ILM *I.E.* [25]	7.9980	7.9873	7.9979	7.9983	7.9988
DE *I.E.* [27]	7.9982	7.9977	7.9986	7.9985	7.9994
Proposed technique	**7.9992**	**7.9991**	**7.9995**	**7.9995**	**7.9997**

A. Security Evaluation

1) Entropy: To examine the amount of randomness, Entropy plays a very vital role. The execution differentiation based on entropy between the old image encryption technique and the implemented technique is represented in Table I. The table predicts that the values which are very near to the perfect parameters (i.e. 8) are given by the proposed technique. On the contrast of other techniques, the implemented approach has the highest entropy.

2) Bar Graph Evaluation: The strength of every pixel is represented by the bar graph. The bar graph helps in escaping the analytical data [1], [35]. Therefore, the bar graph of an encrypted image should be constantly scattered. The bar graph of encoded Sunflower image and different mediums such as red, blue and green is represented in Fig. 5. The bar graph of the encrypted mediums are quite dissimilar to the bar graph of the original mediums is easily predicted through Fig. 5. It is observed that the bar graph of the encoded mediums is constantly scattered. Hence, the implemented technique is proved more secured against all analytical issues.

3) Association coefficient: The analytical data is divulged through the connection between the image pixels. The plain image pixels are correlated with each other. Hence, it is essential to have encrypted image pixels freely associated with each other. The connection between the encrypted image pixels of an implemented technique is calculated by the association coefficient. Eq. (4) is utilized to evaluate the association in different ways, i.e., horizontally, vertically and diagonally.

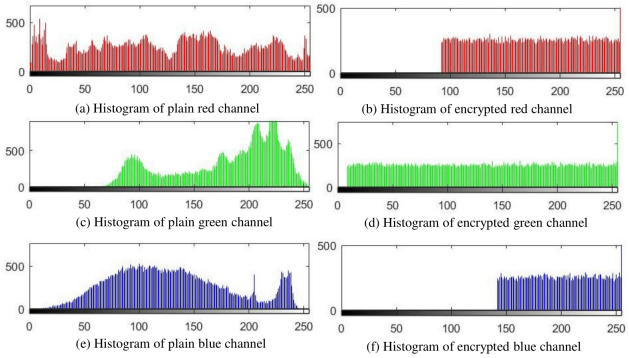

Fig. 5. Sunflower image: Bar Graph of (a) original red medium, (b) encoded red medium, (c) original green medium, (d) encoded green medium, (e)original blue medium, and (f) encrypted blue medium.

TABLE II. DIFFERENTIATION BUILD ON HORIZONTAL ASSOCIATION

Technique	Sunflower	Beans	Female	Duplet	Lena
LW *I.E.* [39]	0.0145	0.0103	0.0056	0.0134	**-0.0129**
NL *I.E.* [40]	0.0070	0.0038	0.0142	-0.0066	0.0171
LV *I.E.* [41]	0.0189	0.0109	0.0131	**-0.0152**	0.0027
ECB *I.E.* [38]	0.0120	0.0208	0.0178	0.0140	0.0082
SPN C *I.E.* [36]	0.0044	0.0134	0.0112	0.0062	0.0057
FMM ILM *I.E.* [25]	0.0010	0.0035	0.0036	0.0004	0.0029
DE *I.E.* [27]	0.0010	0.0014	0.0046	0.0043	0.0020
Proposed technique	**0.0008**	**0.0010**	**0.0008**	**-0.0138**	**-0.0122**

Horizontal, vertical and diagonal association differentiation among the old image encryption technique and proposed approach is portrayed on the Tables II, III, and IV, respectively.

By the review of the mean of the different mediums, the horizontal, vertical and diagonal association of the implemented technique is evaluated under these tables. It is observed from the tables that the implemented technique has the least association in almost every instance. Hence, the implemented technique proves efficient against analytical issues.

Association coefficient of Red medium of original Sunflower image is represented by Fig. 6(a)-(c).

TABLE III. DIFFERENTIATION BUILD ON DIAGONAL ASSOCIATION

Technique	Sunflower	Beans	Female	Duplet	Lena
LW *I.E.* [39]	0.0238	0.0025	0.0064	0.0022	**-0.0269**
NL *I.E.* [40]	0.0078	-0.0021	0.0088	0.0082	0.0243
LV *I.E.* [41]	0.0048	**-0.0075**	0.0072	0.0062	-0.0202
ECB *I.E.* [38]	0.0248	0.0262	0.0082	0.0022	0.0202
SPN C *I.E.* [36]	0.0269	0.0200	0.0220	0.0207	0.0288
FMM ILM *I.E.* [25]	0.0037	0.0027	-0.0003	0.0037	0.0008
DE *I.E.* [27]	0.0047	0.0062	0.0084	0.0068	0.0043
Proposed Technique	**0.0035**	**-0.0076**	**-0.0009**	**0.00011**	**0.0008**

TABLE IV. DIFFERENTIATION BUILD ON VERTICAL ASSOCIATION

Technique	Sunflower	Beans	Female	Duplet	Lena
LW *I.E.* [39]	0.0058	0.0128	0.0038	0.0024	0.0151
NL *I.E.* [40]	0.0101	0.0030	0.0100	0.0002	0.0156
LV *I.E.* [41]	0.0130	0.0121	0.0103	0.0150	**-0.0015**
ECB *I.E.* [38]	0.0120	0.0119	0.0123	0.0104	0.0133
SPN C *I.E.* [36]	0.0125	0.0100	0.0149	0.0090	0.0154
FMM ILM *I.E.* [25]	0.0103	0.0053	0.0028	0.0026	0.0010
DE *I.E.* [27]	0.0126	0.0012	0.0110	0.0130	0.0196
Proposed Technique	**0.0053**	**-0.0040**	**-0.0001**	**-0.0012**	**-0.0016**

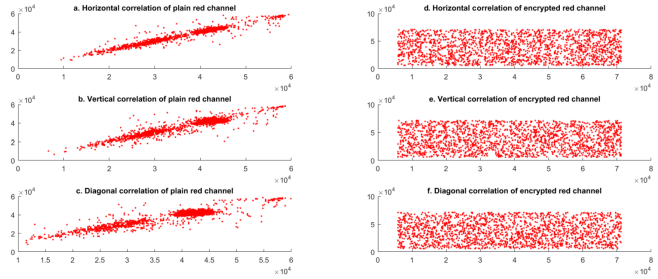

Fig. 6. Sunflower Red medium image before encryption: (a) Horizontal, (b) Vertical, and (c) Diagonal Association (d) Sunflower Red medium image after encryption Horizontal, (e) Vertical, and (f) Diagonal Association

Association coefficient of Red medium of encoded Sunflower image is indicated by Fig. 6(d)-(f). It is observed that the final encoded image is completely random in creation.

4) Comparison evaluation: With the help of Comparison evaluation, the consideration regarding the least changes of the implemented technique can be computed [36]. A very little change is made by the assailant in the plain image. The single private key is used to encode the plain and altered image. Hence, the connection between the plain image and the altered image is found by the assailant. The evaluation of the different attacks is done by using the parameters Number of Pixel Change Rate (NPCR) and Unified Average Change Intensity (UACI).
NPCR can be computed as given below [36]:

$$NPCR = \frac{\sum_{n=j}^{n=h}\sum_{n=1}^{n=j} N_{zz}(n,k)}{h \times j} \times 100 \tag{22}$$

where,

$$N_{zz}(n,k) = \begin{cases} 0 & \text{if} \quad I_{ec}(n,k) = I'_{ec}(n,k) \\ 1 & \text{if} \quad I_{ec}(n,k) \neq I'_{ec}(n,k) \end{cases} \tag{23}$$

UACI can be calculated as given below [36]:

$$UACI = \frac{\sum_{n=1}^{n=h}\sum_{n=1}^{n=j} |I_{ec}(n,k) - I'_{ec}(n,k)|}{255 \times h \times j} \times 100 \tag{24}$$

where, the encoded image having the variance of a single-pixel is represented by $I_{ec}(n,k)$ and $I'_{ec}(n,k)$, respectively. To avoid the different attacks, the highest value of NPCR and UACI are required.

The responsiveness of the implemented technique is estimated with the help of Sunflower image. Based on NPCR and UACI parameters, the execution differentiation among the implemented technique and old encryption technique, respectively is presented under Tables V and VI. The table outcome

TABLE V. DIFFERENTIATION BUILD UPON NPCR (IN %)

Technique	Sunflower	Beans	Female	Duplet	Lena
LW *I.E.* [39]	99.5648	99.5720	99.5769	99.5973	99.5873
NL *I.E.* [40]	99.6189	99.5488	99.5990	99.6372	99.6490
LV *I.E.* [41]	99.4689	99.5667	99.4468	99.6009	99.6010
ECB *I.E.* [38]	99.5266	99.5289	99.5492	99.5496	99.4593
SPN C *I.E.* [36]	99.5089	99.5118	99.5378	99.5460	99.6099
FMM ILM *I.E.* [25]	99.5893	99.5972	99.6347	99.6408	99.5391
DE *I.E.* [27]	99.5170	99.5385	99.5677	99.5494	99.5475
Proposed Technique	**99.63022**	**99.6563**	**99.6734**	**99.6486**	**99.6688**

TABLE VI. DIFFERENTIATION BUILD UPON UACI (IN %)

Technique	Sunflower	Beans	Female	Duplet	Lena
LW *I.E.* [39]	33.3675	33.4872	33.5670	33.5870	33.6094
NL *I.E.* [40]	33.4873	33.4926	33.4538	33.5742	33.3992
LV *I.E.* [41]	33.4304	33.4301	33.4405	33.4506	33.4721
ECB *I.E.* [38]	33.3723	33.4962	33.4908	33.4871	33.4860
SPN C *I.E.* [36]	33.2996	33.2987	33.3773	33.3850	33.3769
FMM ILM *I.E.* [25]	33.3968	33.4559	33.4973	33.4968	33.4984
DE *I.E.* [27]	33.4632	33.4511	33.4794	33.5207	33.4787
Proposed Technique	**33.5826**	**33.5877**	**33.5852**	**33.5894**	**33.6657**

predicts that the implemented technique has better NPCR and UACI parameters in contrast to the existing techniques. Hence, the implemented technique has far better potential to avoid different attacks.

5) Private key scope: To make the brute-force attacks impossible, a huge key expansion is significant for image encryption. The primary parameters of a modified logistic chaotic map that is created from the memetic differential expansion are considered as the private keys under this implemented technique. Different keys are stated as q_0, u_0, t_0, s_1, s_2, s_3, and α. If accuracy is fixed to 10^{-14} then the key space of the implemented technique is given by 10^{98}. To withstand the Brute-force attacks, the key space is considered as sufficient.

6) Private key responsiveness: The implemented technique responsiveness against the private keys has been estimated. With the help of modified logistic chaotic map, the private keys, i.e., q, u, and t are originated by using the primary values ,i.e., q'_0, u'_0, t'_0, s_1, s_2, s_3, and α. With the help of q, u, and t , respectively, the different mediums of M_{ic} such as C_r, C_g, and C_b are encoded. To get the encrypted image, i.e., I_{ec} as output, the encrypted mediums are merged together. The encrypted image utilize the real private keys are represented in Fig. 7(b).

The distinct private keys such as q', u', and t' are originated with the modest change in the beginning variable, i.e., q_0. Afterward, the original image mediums such as C_r, C_g, and C_b are encrypted with the support of the new private keys. With the integration of different encrypted mediums, an encrypted image, i.e., $I^{'}_{ec}$ is received. The encrypted image produce with the help of new private keys is shown in Fig. 7(c). The dissimilarity among the different encrypted images, i.e., I_{ec} and I'_{ec} that has very less differentiation in primary parameters is represented in Fig. 7(d). Fig. 7(e) indicates the decrypted image of Fig. 7(b) with the help of real private keys. The decrypted image which is the outcome of executing the new private keys on the initial encrypted image is indicated in Fig. 7(f). It is observed from the outcome that even if there is very little change in starting parameters of the private keys, the recuperate of the initial image is not possible.

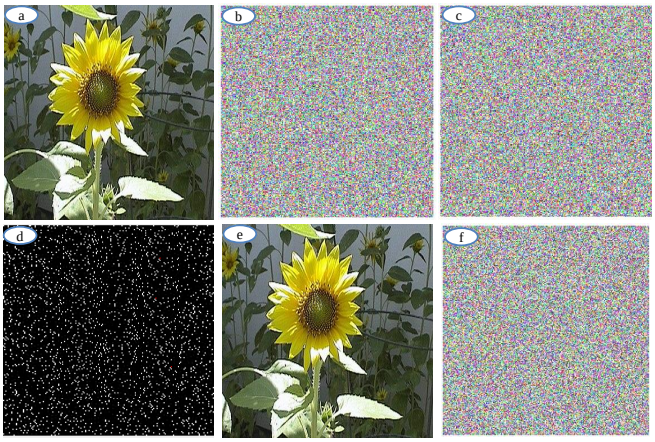

Fig. 7. Private Key Responsiveness: (a) Original Sunflower image, (b) Private keys generate Encrypted image, (c) New Private keys created Encrypted image, (d) Differentiation among (b) and (c), (e) decrypted image create using an initial key, and (f) decrypted image generate using new keys.

TABLE VII. DIFFERENTIATION AMONG I_{ec} AND I'_{ec} IMAGES (IN %)

	Sunflower	Beans	Female	Duplet	Lena
Differentiation	99.9592	99.9798	99.9854	99.9893	99.9984

Table VII represents the Differentiation among I_{ec} and I'_{ec}. It is perceived that the very little changes in the original parameters can result in entirely distinct encrypted images.

7) Peak Signal to Noise Ratio: The productiveness of the encryption approach is used to execute the Peak Signal to Noise Ratio (PSNR) [37]. As known in prior, highest the value of PSNR results in the efficient standard of decrypted images.

The evaluation of the implemented technique and the previous technique of image encryption is represented in Table VIII. It is observed that the Implemented approach results in better PSNR value in contrast to other techniques.

V. CONCLUSION

The issue of the variable tuning linking with the logistic chaotic map is defeated by the implemented technique. The implemented technique used the memetic differential expansion to solve this issue. Based on the distinct popular color images, the virtue of the implemented technique has been evaluated. The average enhancement is perceived in the implemented technique while comparing the outcome of the implemented technique with the existing approach. The proposed technique

TABLE VIII. RELATIVE STUDY WITH THE HELP OF PSNR (IN DB)

Technique	Sunflower	Beans	Female	Duplet	Lena
LW *I.E.* [39]	63.6335	63.4405	63.2536	63.5511	63.3984
NL *I.E.* [40]	67.6652	67.1711	67.2739	68.2491	68.0399
LV *I.E.* [41]	70.7811	71.6982	70.7658	73.7985	72.7544
ECB *I.E.* [38]	68.2811	68.9492	68.2898	68.7765	68.2988
SPN C *I.E.* [36]	69.2768	69.8972	69.9097	69.0676	69.3988
FMM ILM *I.E.* [25]	74.6476	74.2967	74.9758	74.7876	74.8960
DE *I.E.* [27]	78.6695	78.2587	78.4973	78.1284	77.6582
Proposed Technique	**80.6996**	**86.8789**	**83.4994**	**82.2999**	**87.7763**

has better Entropy, NPCR, UACI and PSNR values , i.e. 0.32%, 0.20%, 0.22%, and 30.5% (dB), respectively. The implemented technique has decreased the association coefficient by 2.9%. The outcome divulges that implemented technique gives better security and effectiveness of images in contrast to all other existing techniques.

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Associative Classification using Automata with Structure based Merging

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***Abstract*—Associative Classification, a combination of two important and different fields (classification and association rule mining), aims at building accurate and interpretable classifiers by means of association rules. The process used to generate association rules is exponential by nature; thus in AC, researchers focused on the reduction of redundant rules via rules pruning and rules ranking techniques. These techniques take an important part in improving the efficiency; however, pruning may negatively affect the accuracy by pruning interesting rules. Further, these techniques are time consuming in term of processing and also require domain specific knowledge to decide upon the selection of the best ranking and pruning strategy. In order to overcome these limitations, in this research, an automata based solution is proposed to improve the classifier's accuracy while replacing ranking and pruning. A new merging concept is introduced which used structure based similarity to merge the association rules. The merging not only help to reduce the classifier size but also minimize the loss of information by avoiding the pruning. The extensive experiments showed that the proposed algorithm is efficient than AC, Naive Bayesian, and Rule and Tree based classifiers in term of accuracy, space, and speed. The merging takes the advantages of the repetition in the rules set and keep the classifier as small as possible.**

***Keywords*—Associative classification; automata; ranking and pruning; rules merging; classification**

I. Introduction

Classification considers to be one of the main pillars in DM and ML [1, 2]. It is a data analysis technique, used to categorize data into different classes based on some common characteristics or associations in the data. Generally, classification consists of two basic steps i.e. a) preparation of classification model - Classifier, from available data (training dataset) and b) Classification - the prediction of unknown class label, based on the classifier model.

Classification is sometime called a predictive data mining technique due to its predominant applications in predictive domains. It is successfully applied in health care and biomedicine [3], geographical information systems, [4], marketing [5], agriculture [6], risk management [7], web traffic prediction [8], and the list continues. The broader applications of classification and its importance in some areas, particularly in health, finance, and agriculture became the motivating factors for this research.

DM contains a rich set of classification models; specifically, Support Vector Machine [9], Rule Based [10], Decision Tree [11, 12], Bayesian classification [2], k - Nearest Neighbor [13], and AC [14]. Among all, AC is relatively new and promising [15, 16, 17, 18, 19, 20, 21, 22, 23, 24] as it combines the best approaches of association rules mining (ARM) and classification. AC is based on ARM where, first, the strongest Class Association Rules (CAR) are discovered from dataset, followed by converting those rules into classifier model. Those stronger associations from the data, in the form of CAR, make the classifier more logical and improve accuracy.

After the introduction of AC in 1997, numbers of algorithms are developed in this family e.g. CBA [14, 25], CMAR [18], CPAR [21], MCAR [19], MAC [26], CMARAA [27], MRAC & MRAC+ [15], DAC [23], CBA-Spark and CPAR-Spark [24] and G3P-ACBD [28]. Almost all consist of three basic steps - a) Association rule generation, b) Classifier building - rule pruning and rule ranking c) Classification of unknown records using the classifier.

CAR, used by AC is a variation of ARM whose right hand side (consequent) is a class label instead of ordinary attribute. The ARM generates those CARs which passes minimum support and confidence threshold and classifier is then built on the basis of these CAR. AC further applies rule ranking and rule pruning to minimize the number of rules in the classifier. The reason for reduction is to make the classifier smaller which improves the efficiency of the classification. The small number of rules in the classifier is advantageous in the context of speed but is less appreciated for accuracy [17, 29, 30]. In addition to the negative effects on accuracy, these two additional steps also add their own computational overhead to the classifier.

Besides the computational overhead of rule pruning and rule ranking, AC has two other limitations. The first is the reduction of rules which generally eliminates the more significant rules and therefore may leads to reduce accuracy [17, 29, 30]. Secondly, pruning and ranking both require a detailed insight of data so as to be able to wisely decide upon the pruning and ranking criteria, e.g.: how to choose the bottom line, what should be included and what should be removed from the classifier? Further, the term "interestingness" is relative that means different things to different experts even in the same domain. All these facts make it more complicated to decide upon an appropriate pruning strategy.

Similarly, ARM generate exponential number of rules that does not make it suitable for very large dataset. Because the number of rules generation and then pruning and ranking

strategies require more time which make the use of these techniques less effective [31]. Therefore, a new storage structure is necessary that can help reducing the size of dataset in order to make the processing less time consuming while improving the accuracy.

Keeping in mind these shortcomings, we propose to replace ranking and pruning with our automata based. On one side it will reduce the computational overhead of these steps while on the other side it will also minimize the loss of information by avoiding the unnecessary pruning. In order to achieve the goals of the eliminating redundancy, a new merging criteria based on structure similarity is introduced that would help to reduce the classifier size in order to improve the efficiency. Furthermore, automata based storage structure is designed to make the classification of large dataset more efficient and reduce the space allocation during classification.

The incorporation of automata observed a number of properties: including; a) its efficient structure to store data [32], b) The capability of loss-less absorbency of redundant rules, c) its sequential nature [33] to perform efficient string matching [34, 35], and the ability to deal with frequent and rare class at the same time. Therefore, the integration of automata and AC resulted in more efficient and robust for both AC as well as classification in general.

The rest of paper is organized as follows. The design of Associative Classification using Automata phase in Section II. Conflict Resolution is highlighted in Section III followed by classification of test instances in Section IV. The weighting criteria is discussed in Section V. The Section VI explains the environment and parameters used in the experiments, followed by the dataset and algorithm selected for experiments in Sections VII and VIII. Section IX deals with accuracy comparison and analysis. Finally, the complexity analysis were estimated in Section X, the paper was concluded in Section XI and future work is highlighted in Section XII.

II. Associative Classification using Automata

In this section the steps taken towards building ACA are discussed. The automata is used as a replacement of pruning and ranking phases of traditional AC algorithms. Automata also provides an efficient way for accessing and processing the test instances during classification. The following subsections highlight different aspects of the ACA.

A. Building Automata from data

This section deals with the algorithm designed to develop the automata from dataset. The task is divided into two sub task where first the CAR are generated using ARM and then automata is built on those CARs.

B. Class Association Rules Generation and Rules Pruning

Associative Classification requires CAR as a basis for classification, therefore, before building the Automata model, CAR needs to generated. In order to generate the CAR, any ARM algorithm can be used. In the current implementation of ACA, apriori is used. One of the inherited limitations of CAR is its exponential number of rules which are complex to handle efficiently, thus, after the generation of CAR, rule pruning is the mandatory phase of other techniques to eliminate the redundant or less interested rules. In ACA, the pruning and ranking phase is replaced by the use automata which has the capability to handle with the redundant rules.

C. Building Automata using CAR

A new algorithm, *Automata_Construction*, is developed and discussed in this section. The discussion and explanation of the algorithm uses Table I as an example that represents CARs for IRIS2D dataset which is available at UCI repository [36]. The CARs presented in this section are generated using Weka's Apriori algorithm with default parameters. In Table I there are a total of nine rules where each row represents one rule. Every row consists of, specifically: a rule number (Column R_No), attributes (e.g. columns PatelLength (PL) and PatelWidth (PW)) and class label (column Class). Each cell then represents the value for the attributes (the column in which the value appears in the table) for the rule in which row it is shown in the table: i.e. "4.75-max" is the value of PatelLength for R_No 5 and 9. The process of building automata automata from Table I is summarized in Algorithm 1.

The key part of the ACA is that of transition function (δ) that defines the rules of movement from one state to another. The general form of transition function is $\delta = Q \times \Sigma \rightarrow Q$ which means that one can move from any state (from Q) using any input symbol (from Σ) to any state (in Q). CARs in Table I represent δ for algorithm.

Algorithm 1 Creation of NFA from Class Association Rules - CARs

Name: Automata_Construction
Input: Set of association rules (ruleSet).
Output: Set of Automata

```
create Automata with rule1 from ruleSet and increment Level

while ruleSet ≠ φ do
    read rule one by one

    if no_conflict(ruleSet, set_FA) then
        insert into Automata

    else
        Add rule to conflictRuleSet

    end if
end while
Update ruleSet = conflictRuleSet

Call Automata_Construction with updated ruleSet
```

In order to represent Table I as automata, it fed to the algorithm as δ for $A = \{Q, \Sigma, \delta, q_0, F\}$ where, specifically: Q is the union of set of all attributes and distinct class labels from datasets; Σ is the collection of distinct values of all attributes; q_0 is the start state and can be any attribute from set of Q. Finally F, set of final states, is the set of distinct class

TABLE I. CARS FOR IRIS2D DATASET, GENERATED USING WEKA 3.7.10

R_No	PatelLength (PL)	PatelWidth (PW)	Class
1	min-2.45		Iris-Setosa - C1
2		min-0.8	Iris-Setosa - C1
3	min-2.45	min-0.8	Iris-Setosa - C1
4		1.75-max	Iris-Virginica - C2
5	4.75-max	1.75-max	Iris-Virginica - C2
6	2.45-4.75		Iris-versicolor - C3
7	2.45-4.75	0.8-1.75	Iris-versicolor - C3
8		0.8-1.75	Iris-versicolor - C3
9	4.75-max		Iris-Virginica - C2

labels. Example 1: This example shows how Table I represents all input elements required by automata. All rules in Table I represent δ. These rules, actually, provide the mechanism of movement between different states of automata. Set of states are:
Q = {PatelLength, PatelWidth, C1, C2 and C3} (Collection of all attributes and distinct class label).
Input symbols consist of:
$\Sigma = \{"min - 2.45",\ "2.45 - 4.75",\ "4.75 - max",\ "min - 0.8",\ "0.8 - 1.75",\ "1.75 - max"\}$ (set of distinct values of all attributes.)
q_0 can be any attribute that starts a rule; e.g. for rule 1 & 3 q_0 is patelLength, while for rules 2 & 4, q_0 is patelWidth.
The set of final states are $F = \{C1,\ C2,\ C3\}$ (distinct class labels). The transition function for ACA has additional characteristics and some restrictions that are explained in detail below.

D. Properties of Automata in ACA

In the context of ACA the automata observed the following properties which impose some level of determinism and also helps to control the number of transition (movement from one state to other state) in δ. Further, if an attribute q_i comes before attribute q_j in the dataset, then the former is called the predecessor while the latter is the successor. It imposes sorting order of attributes and formally, this can be shown as follows:

$$q_i \prec q_j \ iff\ q_i\ preceeds\ q_j\ in\ the\ datset \tag{1}$$

Example 2: PatelLength comes before PatelWidth in the dataset, therefore PatelLength is predecessor and PatelWidth is successor. Keeping in view this assumption, Automata in ACA will also observe the following properties.

1) This property defines the start state conflict and its resolution.

$$EveryAutomata\ \ should\ have\ one\ and\ only\ one\ start\ state\ and\ it\ will\ be\ the\ first\ attribute\ of\ the\ rule. \tag{2}$$

Example 3: R_i = (PL) : $min - 2.45 \rightarrow Iris - Setosa - C1$
R_j = (PW) : $min - 0.8 \rightarrow Iris - Setosa - C1$
R_i and R_j have different first attributes; therefore they cannot be absorbed by a single automaton and accordingly creates a separate automaton for each rule.

2) From any state from Q, using any input symbol from Σ, a transition can be made to any successor state (except final state(s)) i.e.

$$\delta = q_i \times \Sigma \rightarrow q_j \mid q_i \in Q\ \Lambda\ q_i \prec q_j\ \Lambda\ q_j \in (Q - F) \tag{3}$$

This property allows 'forward only' moves and this restriction is used to control the increase in number of transitions.
Example 4: From state PatelLength the transition can be toward PatelWidth, but the reverse is a violation of this Property (3).
In case, if the transition is toward final states, then ACA maintains the following sub property.

a) There should be no two transitions in automata where two different final states can be reached by the same input from the same state. i.e.

$$\nexists\ q \times \alpha \rightarrow f_i\ \Lambda\ q \times \alpha \rightarrow f_j \mid q \in Q;\ \alpha \in \Sigma;\ f_i\ and\ f_j \in F\ \Lambda\ i \neq j \tag{4}$$

Example 5: If $R_i = PatelLength : min - 2.45 \rightarrow C1$ then
$R_j = patelLength : min - 2.45 \rightarrow C2$ is illegal (same state, same input label but different final states.) R_j is a conflicting rule and makes a separate Automata.

3) If there is a transition from state q_k on input symbol α to final state f_i and q_k is the immediate successor of f_i, then there should be no transition to non-final state on α. Formally

$$If\ \ q_i \times \alpha \rightarrow f\ where\ f \in F\ then\ \nexists\ q_i \times \alpha \rightarrow F - f \tag{5}$$

This property maintains determinism at the second last state of the automata. It reduces ambiguity which also minimizes the rate of miss-classification.

After the enlightenment of above properties and assumptions for automata, now the algorithms is explained with an example. In this example Table I is used but for the sake of simplicity, it is converted to "attribute-value" pairs as shown in Table II. In the converted form, every "even" column represents the name of an attribute and its corresponding "odd" column represents the value for that attribute. Formally, column $2i$ represents attribute i while $(2i + 1)$ represents the value for attribute i and $0 \leq i < k$ where k is the total

number of attributes. Thus *col0* represents PatelLength and *col1* is its value. Similarly *col2* represents PatelWidth and *col3* is its value. The only exception is the last column which represents class label and therefore has no attribute name. The first column representing the rules ID is only for referencing purpose and it is not part of the actual table. Each cell has a short name for values, which is given inside parentheses, and will be used in figures during examples.

The *Automata_Construction* (Algorithm 1) starts from first rule by reading the first "attribute - value" pair and starts building automata. The first attribute of the rule becomes start state and its value becomes the label towards the next state. While reading next pair, the newly-read attribute becomes the next state and establishes a link with the previous label. Its value now becomes the label for the next state and the procedure continues until the class label is reached. The class label is marked as a final state which ends the first rule. The same procedure is repeated for all rules. Example 6 explains the procedure below.

Example 6: The algorithm starts from rule 1 and reads the first attribute and its value such as col0 and col1 and makes the first part of automata, as shown in Fig. 1(a).

Next, col2 and col3 are empty; therefore the algorithm reads the last column and makes it the final state as shown in Fig. 1(b).

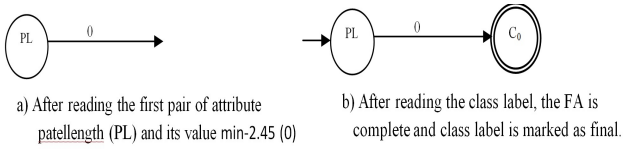

Fig. 1. Automata construction for Rule 1 from Table II

Algorithm 1 is repeated for all rules and every rule is added to the existing automata one by one. During the construction, the algorithm checks for the fulfillment of the above mentioned properties. In the case of violation, the rule that results in violation is marked as a conflicting rule and it becomes a candidate for a new automaton. The process continues until there are no more rules in the rule set. The step wise automata is shown in Fig. 2 to 6.

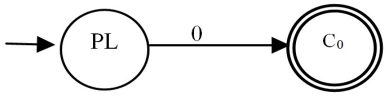

Fig. 2. Automata 0 after reading rule 1 from Table II

When the algorithm reads rule 2, it will starts from PW which is different from the start state of Automata 0 (violation of Property (1)). Therefore, Rule 2 will make new Automata as shown in Fig. 3.

After reading Rule 3, the algorithm will compare it with Automata 0. There is no conflict (i.e. the rule is not unique) and therefore Automata 0 will absorb rule 3 (Fig. 4).

Similarly when rule 4 is read, it violates Property (1) (i.e it is unique rule), therefore it will compare the rule with

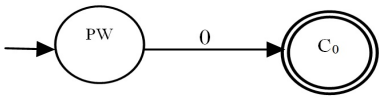

Fig. 3. Automata 1 after reading rule 2 from Table II

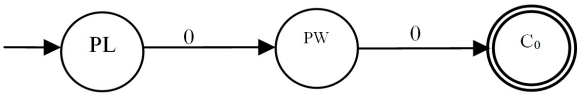

Fig. 4. Automata 0 after reading rule 3 from Table II

Automata 1, and provided there is no conflict, rule 4 will be added to Automata 1 (Fig. 5)

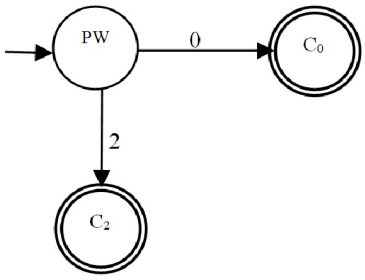

Fig. 5. Automata 1 after reading rule 4 from Table II

The same process will be repeated for all nine rules and, every time, the comparison will take place from Automata 0 onwards. The Automata with no conflicts will absorb the incoming rule; otherwise Algorithm will construct new Automata for the rule. The stepwise Automata are summarized in Fig. 6.

III. Conflict Resolution

In order to handle conflicts, every rule starts comparison with the first automata and try to absorb that rule. If the rule violates any property explained in Section II-D that specify conflicts, algorithm checks it with the next level automata and so on until either one of the existing automata absorbs the incoming rule or new automaton is built for that rule. Conflict resolution at this stage results in building new automata for the conflicting rule. At this stage the ACA ensures to shrink the redundant rules and absorb into similar automata.

IV. Classification of Test Instances

Finally, the test instances are used for classification using the new model. ACA_Classifier is used for prediction of unlabeled instance to label it with correct class. The classification algorithm is summarized in Algorithm 2.

During classification, there are two possibilities. If there is only one automaton in model, then the procedure is simple and all the test instances are tested against the single automaton. While in the case of multiple automata, the classification starts from the higher level of automaton. For example, the classification of IRIS2D automata of Fig. 6 starts from automata 1 and if it fails to classify the test instance, or the Weighted

TABLE II. CONVERTED FORM OF CARS (TABLE I) INTO "ATTRIBUTES-VALUE" PAIRS

Rule_No	col0 (att1)	col1(Val1)	col2(Att2)	col3(Val2)	col4(Class_label)
Rule 1	PatelLength (PL)	min-2.45 (0)			Iris-Setosa (C0)
Rule 2			PatelWidth (PW)	min-0.8 (0)	Iris-Setosa (C0)
Rule 3	PatelLength (PL)	min-2.45 (0)	PatelWidth (PW)	min-0.8 (0)	Iris-Setosa (C0)
Rule 4			PatelWidth (PW)	1.75-max (2)	Iris-Virginica (C2)
Rule 5	PatelLength (PL)	4.75-max (2)	PatelWidth (PW)	1.75-max (2)	Iris-Virginica (C2)
Rule 6	PatelLength (PL)	2.45-4.75 (1)			Iris-versicolor (C1)
Rule 7	PatelLength (PL)	2.45-4.75 (1)	PatelWidth (PW)	0.8-1.75 (1)	Iris-versicolor (C1)
Rule 8			PatelWidth (PW)	0.8-1.75 (1)	Iris-versicolor (C1)
Rule 9	PatelLength (PL)	4.75-max (2)			Iris-Virginica (C2)

Ratio (WR) (explained in section V) is less than 100 percent, it checks the test instance against Automata 0. Thus, if there are n automata, the comparison will start from $Automata_n$, in case of failure or smaller WR, the next comparison will be against $Automata_{n-1}$ and the process will continue till $Automata_1$. In case of less WR at the last automata, the class label with the highest WR will be selected as a class label. Weighted ratio calculation is explained in next section.

Algorithm 2 Classification of test dataset

Name: ACA_Classifier
Input: Set of Automata
testData
Output: Classified Dataset

while $testData \neq \phi$ **do**
  read rule one by one
  $acc = 0.0$
  $level = total\_autumata$
  while $Level > 0$ & $acc != 100\%$ **do**
    while $rule \neq \phi$ **do**
      if attribute-value pair matches **then**
        increment *hit* by 1
      else
        if Attribute or value does not match **then**
          increment *mis* by 1
        end if
      end if
      Read next pair
    end while
    $ratio = (hit/totalStates)*(hit+totalStates)*2$
    if $ratio > acc$ **then**
      $acc = ratio$
      $testClassLabel = autmataClassLabel$
    end if
    Decrement Level by 1
  end while
end while

V. WEIGHTED RATIO MEASUREMENT

The classification of test instances is based on the "attribute-value" pairs, similar to the one used during automata construction. Algorithm 2 verifies both attribute and its value to a single state. If both match, the process then moves to the next state and reads the next pair from the test instance. Every match in automata increments "hit", while mismatches incur an increment of a "miss" variable. At the time of classification, algorithm check the ratio between "hit - miss" and the highest WR is considered the predicted class for the instance.

The WR is defined by Equation No (6). This equation gives a high weight to those automaton with maximum number of matching states. For example, for three hits out of six states, automata will give a high ration as compared to 2 hit out of 4 states; while the average for both is 0.5. Here the focus is on the maximum number of matches instead of the maximum average where 5 out of 10 and 10 out of 20 are equal using a simple average. However, Eq (6) will give preference to 10 out of 20 due to maximum numbers of correct matches. It results in a stronger classification as a consequence of high number of similarity with respect to the number of attributes. Further, if the numbers of hits are the same, then it gives preference to a lesser number of mismatches; therefore, in calculating weight, Eq (7) will increase the weight of low miss-count and decrease that of the high miss-count.

$$Ration = \omega + hit\_counts \tag{6}$$

$$\omega = \left(\frac{1}{miss\_count}\right) * \left(\frac{1}{total\_attributes}\right) \tag{7}$$

Example 7: Table III and Table IV correspond to contact lenses and dermatology datasets, respectively. In each table, row represents the outcome of comparison of test instance with one automaton. Column 1 (S No) is an identifier for each automaton while column 4 (Total) represents the total number of states in that automaton. In Table III, a test of test-instance is shown with 6 different Automata. The table also lists the hit and misses counts. According to Eq (6), the algorithm will select Q1 because it has the maximum number of hits and a lesser number of misses as compared to Q3. In this case, the simple average will also select Q1 because the average is highest among all; despite the issue that a single hit of Q5 is given preference over 2 hits of Q6. Now consider Table IV: the simple average will now select Q1 as a result of the highest average and will ignore Q2 where 14 attributes match out of 16. However, ACA will choose Q2 because it gives the highest ration.

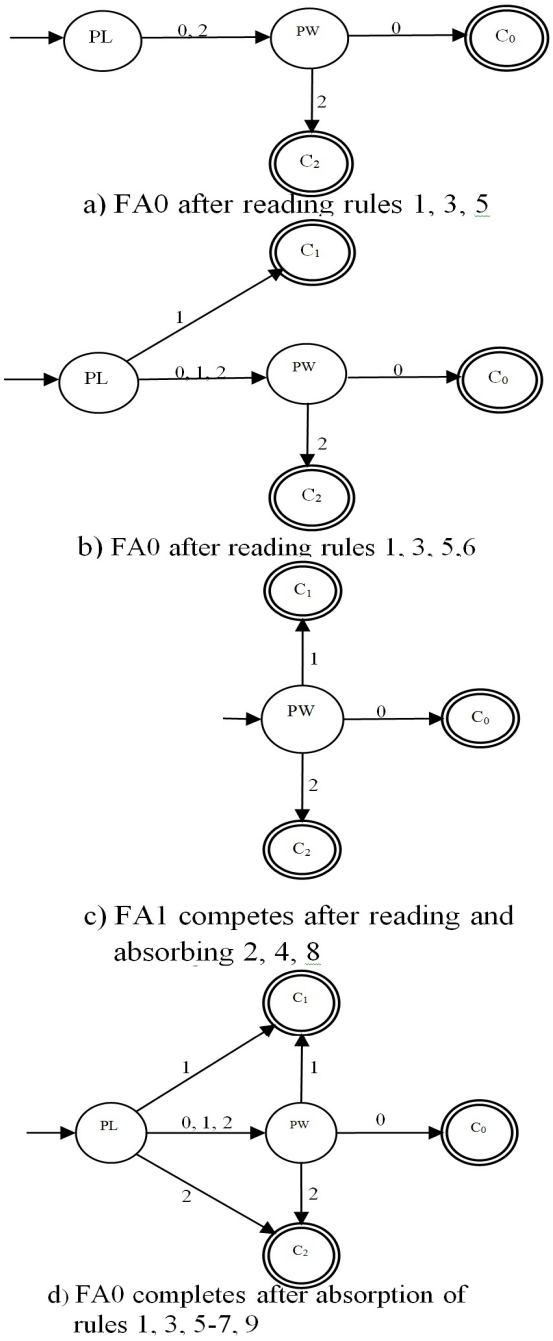

Fig. 6. Automata 0 and Automata 1 after reading all rules from Table II. Figures c) and d) are final Automata for the classification Algorithm

VI. Results and Discussion

The ACA was implemented using Java 7, on Windows 8.1 running over 64bit, core i7 2.6GHz machine with 8GB of memory. The results of other techniques are generated using Weka 3.7.13 on the same system with the above specifications. In order to simplify the regeneration of results in Weka, all the experiments were conducted with default parameters or otherwise explained in the corresponding sections. The numeric datasets were discretized using using unsupervised discretizer of Weka, because most of the classification techniques did their experiments on the same grounds.

TABLE III. Partial Automata from Contact Lenses dataset for weighted class label comparison (Total No of Attributes: 4)

S No	Hit	Miss	Total	Eq (I)	Average
Q1	3	1	4	3.2	0.75
Q2	2	1	3	2.2	0.667
Q3	3	2	5	3.1	0.6
Q4	2	2	4	2.1	0.5
Q5	1	1	2	1.2	0.5
Q6	2	3	5	2.067	0.4

TABLE IV. Partial Automata from dermatology dataset for weighted class label comparison(Total No of Attributes: 16)

S No	Hit	Miss	Total	Eq(I)	Average
Q1	8	1	9	8.063	0.889
Q2	14	2	16	14.031	0.875
Q3	2	1	3	2.063	0.667
Q4	3	2	5	3.031	0.6
Q5	4	3	7	4.021	0.571
Q6	5	4	9	5.016	0.556

VII. Selection of datasets for Experiments

The most commonly cited datasets [18, 19, 21, 26, 37, 38] are selected for the experiments. These all datasets are available at UCI Machine Learning Repository [36]. In order to show the effect of new technique on different dataset, the datasets were divided into four categories, namely: a) Small Discrete Datasets, b) Large Discrete Datasets, c) Small Continuous Datasets, and d) Large Continuous Datasets. The discrete and continuous devision is based on the nature of data types i.e. Categorical or Numeric, while the distribution into small and large datasets is provided for the purpose to explain the effects of ACA on the smaller and larger datasets. The following sub-sections explain these categories in detail.

A. Small Discrete Dataset

Small discrete datasets include those datasets which produce less than are equal to 50,000 association rules. The reason behind setting the limit to 50,000 is that this number of association rules are taking much longer time on the system with small memory i.e. 2GB or 4GB and in some cases may lead to system halt. The experiments during association rule generation showed that in general when the number of attributes are 9 or more, then the numbers of association rules exceed 50,000 under minimum threshold for support and confidence for rules generation are set to 1% and 100% respectively. The datasets in this category are displayed in Table V. The table shows that there are datasets with 2 to 4 classes while the number of instances in datasets ranges from 12 to 1728. Similarly, the attributes ranges from 5 to 7.

B. Large Discrete Dataset

The large dataset in discrete category contain those datasets which either generate more than 50,000 rule under the threshold of 1% support and 100% confidence or the number of

TABLE V. DETAILED DESCRIPTION OF SMALL DISCRETE DATASETS

Dataset Name	Attributes	Instances	Class
weather.nominal	5	14	2
balloons	5	20	2
contact-lenses	5	24	3
shuttle-landing-control	7	15	2
car	7	1728	4

attributes are 9 or more. This category includes Vote, Zoo, Tic-Tac-Toe, Postoperative Patient Data, Breast Cancer, Nursery, and Mushroom. The detailed description is shown in Table VI. This category has the datasets where the attributes ranges from 9 to 23 while the number of instances are as minimum as 90 the maximum of 12960. Furthermore, these datasets also have more classes which ranges from bi-class problem to 21classes.

TABLE VI. DETAILED DESCRIPTION OF LARGE DISCRETE DATASET

Dataset Name	Attributes	Instances	Class
postoperative-patient-dat	9	90	3
nursery	9	12960	5
breast-cancer	10	286	2
tic-tac-toe	10	958	2
zoo	17	101	2
vote	17	435	2
primary-tumor	18	339	21
Mushroom	23	8124	2

C. Small Continuous Datasets

This category consists of those datasets that have any number of attributes with continuous/numeric data types. These datasets were discretized with the Weka built in feature i.e. unsupervised discretizer. Then the similar criteria of the number of rules were applied to distinguish between small and large datasets. Those datasets which are able to generate 50,000 or less rules are included in this category. The datasets in this category are IRIS2D, IRIS4D, Balance Scale, TEA, Hayes Roth, Weather Nominal, Data Banknote, and Liver Disorder. Table VII shows the detailed description of these datasets. The number of rows in this category in the similar range of small discrete dataset. bi-class and multi-class, both typoe of datasets are included in this category. Similarly, the number of instances also ranges from 14 to 1373.

TABLE VII. DETAILED DESCRIPTION OF CONTINUOUS SMALL DATASETS

Dataset Name	Attributes	Instances	Class
iris2D	3	150	3
weather-numeric	5	14	3
hayes-roth	5	28	4
iris	5	150	3
balance-scale	5	625	3
data_banknote	5	1373	2
tae	6	151	3
liver-disorders	7	345	2

D. Large Continuous Datasets

The final category consists of large dataset with continuous data types. The datasets which have any number of attributes with numeric data type and have the ability to generate more than 50,000 association rules under the threshold of 1% support and 100% confidence are included in this category. This includes Diabetes, Breast Cancer, CMC, Page Block, Labor, Heart-C, Heart-h, Anneal, Ionosphere, Dermatology, Glass, Hepatitis, and wine. Table VIII shows the detailed description of large continuous datasets. The table can show that this category is comparatively diversified in terms of attributes, number of classes and number of rows. The number of attributes in this category are as many as 39 which are considered quite high for AR algorithms. Similarly, both bi-class and multi-class problems are included in this category.

TABLE VIII. DETAILED DESCRIPTION OF LARGE CONTINUOUS DATASETS

Dataset Name	Attributes	Instances	Class
diabetes	9	768	2
Glass	10	214	6
w-breast	10	699	2
cmc	10	1473	3
page-blocks	11	5473	5
Wine	14	178	10
hungarian-14-heart-diseas	14	294	2
heart-c	14	303	2
labor	17	57	2
Hapititus	20	178	2
Dermatology	35	366	6
Ionosphere	35	366	2
Anneal	39	898	5

VIII. SELECTION OF ALGORITHMS FOR COMPARISON

ACA was compared with three classes of classification algorithms. The first is obviously based on association rules, so as to give comparison with its own family members. The algorithms in this class are CBA [25] and LAC[39]. The second class of algorithms is rule-based and Tree Based. This class of algorithms is similar in nature with AC and have J48 [12], CART [40], BFTree [40], Jrip (Ripper) [41], PART [42], DecisionTable, and ZeroR. Finally, Average One Dependence Estimator (AODE) [43], A2DE [44], Naive Bayes, and Bayes Net [45] is selected from Bayesian Family which considers a family of the most prominent classifiers with reasonably high accuracy.

IX. COMPARISON OF ACA WITH OTHER CLASSIFIERS BASED ON ACCURACY

This section deals with the comparison of ACA with different classifiers based on accuracy. The comparison is provided with Associative Classifiers, followed by Rules and Tree based classifier, and finally with Naive Bayesian family of classifiers.

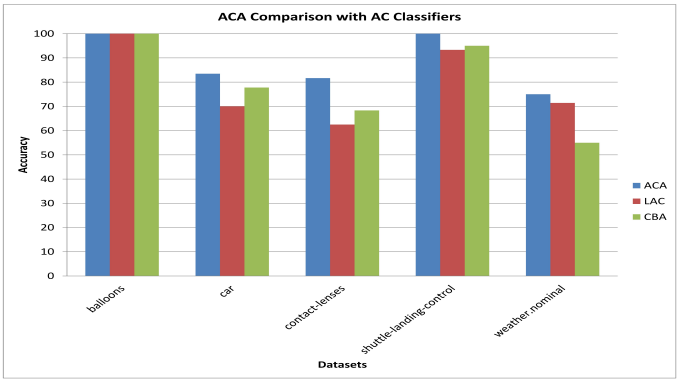

Fig. 7. ACA Comparison with AC Classifiers on small discrete datasets

A. Accuracy Comparison of ACA with Associative Classifiers

The accuracy comparisons with other associative classifiers are discussed in detail in this section. Two classifiers are selected i.e. CBA and LAC from AC classifiers. CBA is the most commonly referenced associative classifier and the latest implementation is used in these experiments. Lazy Associative Classifier is a based on maximum number of rules as compare to CBA. The ACA claims that additional rules might increase the accuracy therefore LAC was chose for comparison with ACA to give insight of rules' effects on accuracy. The discussion is divided into four section where each section discusses individual category of dataset for accuracy analysis.

1) Accuracy comparison with small discrete datasets: In this section, the analysis of ACA with CBA and LAC over small discrete datasets are presented. Table IX and Fig. 7 shows the results of the all three classifiers. The table shows that ACA is performing better than CBA and LAC in most of the datasets. The reason for high accuracy is that ACA is using large number of rules as compare to other classifiers which leads to more accurate results. Secondly, because the datasets are relatively small, the generated rules set is comparative small and complete.

TABLE IX. ACCURACY COMPARISON OF ACA WITH ASSOCIATIVE CLASSIFIERS OVER SMALL DISCRETE DATASETS

Dataset Name	ACA	LAC	CBA
balloons	**100.00**	**100.00**	**100.00**
car	**83.49**	70.02	77.78
contact-lenses	**81.67**	62.50	68.33
shuttle-landing-control	**100.00**	93.33	95.00
weather.nominal	**75.00**	71.42	55.00

2) Comparison with small Continuous datasets: Next, The ACA is compared with small continuous datasets which were discretized using Weka's discretizer utility. Table X and Fig. 8 presents the results of the experiments. It shows that ACA outperform the AC classifiers in most cases while in balance scale and weather numeric datasets ACA did not perform well. Although in general ACA loses in two dataset but the win loss ratio is $7/8$ with individual algorithms where ACA was surpassed by Balance Scale and Weather Numeric by LAC and CBA, respectively.

TABLE X. ACA COMPARISON WITH AC CLASSIFIERS OVER SMALL CONTINUOUS DATASETS

Dataset Name	ACA	LAC	CBA
balance-scale	80.11	**88.96**	45.76
data_banknote	**98.86**	97.88	68.37
hayes-roth	**89.57**	76.51	37.91
iris	**96.67**	**96.67**	66.00
iris2D	**98.67**	94.00	66.00
liver-disorders	**71.43**	66.08	57.98
tae	**69.67**	58.27	34.42
weather-numeric	60.00	35.71	**70.00**

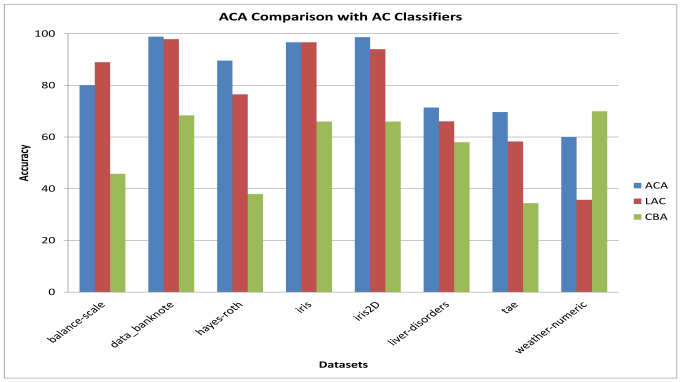

Fig. 8. ACA Comparison with AC Classifiers on small continuous datasets

3) Comparison with Large Discrete datasets: This section discuss the results of ACA with AC classifiers over large discrete datasets. Table XI and Fig. 9 shows the results. Experiments shows that ACA performs better in four out of seven datasets. The extensive experiments showed that those large datasets where the number of distinct values per attributes are small, the ACA performance is lower. The reason is that it results in smaller Automata where conflict of classes increases and even the weighted selection of classes, sometime, unable to produce the highest accuracy. This is the default sequential nature of automata. In individual comparison, the win loss ratio is $5/2$ and $6/1$ with LAC and CBA respectively which is reasonably high. Similarly on the average, the accuracy of ACA is higher than other AC classifiers.

TABLE XI. ACA COMPARISON WITH AC CLASSIFIERS OVER LARGE DISCRETE DATASETS

Dataset Name	ACA	LAC	CBA
breast-cancer	**89.66**	73.77	70.30
nursery	86.79	**92.81**	66.25
postoperative-patient-dat	**73.50**	71.11	68.56
primary-tumor	**54.41**	36.87	38.91
tic-tac-toe	**88.01**	67.22	65.34
vote	68.47	91.72	**94.73**
zoo	86.10	**91.08**	60.39

4) Comparison with Large Continuous datasets: Finally, this section discusses the comparison of ACA with AC classifier over large continuous datasets. It show the strength and

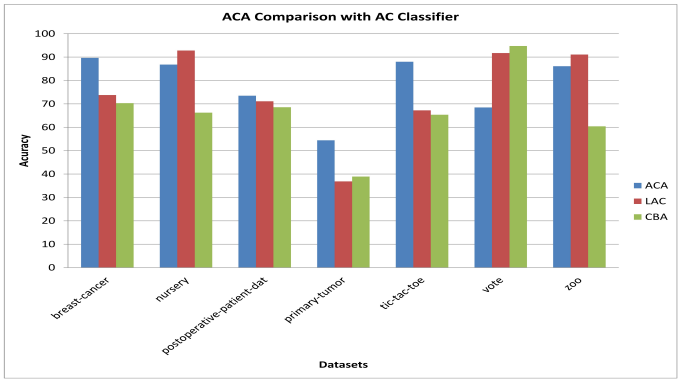

Fig. 9. Accuracy Comparison with AC Classifiers over large discrete datasets

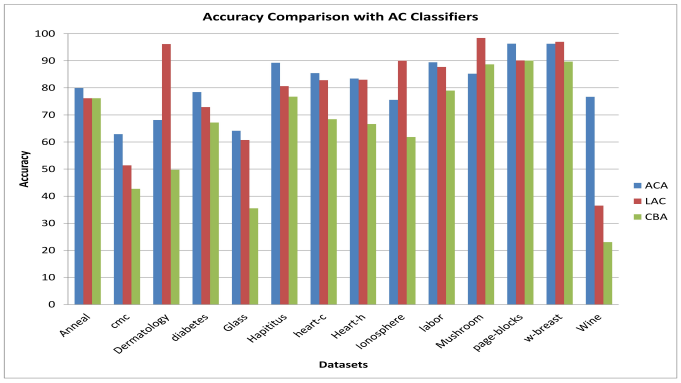

Fig. 10. Accuracy Comparison with AC Classifier over large Continuous datasets

scalability of ACA that as the datasets increase, the accuracy improves. The reason behind is that the large dataset generates more interesting rules and when the number of interesting rules increases, it positively effect the accuracy. Further, The number of distinct values per attributes is larger as compare to Large Discrete dataset and therefore it results in larger automata that produce higher accuracy. Table XII and Fig. 10 shows the results of classifiers. The win loss ration with individual classifier is 11/3 with LAC and 14/0 with CBA. The reason for CBA low performance is the size of dataset as well as less number of rules for their building. While LAC consider a reasonably large rule set from CBA and hence perform better than CBA. In overall ACA beat AC classifiers by 10 datasets out 14.

TABLE XII. ACCURACY COMPARISON WITH AC CLASSIFIERS OVER LARGE CONTINUOUS DATASETS

Dataset Name	ACA	LAC	CBA
Anneal	**79.92**	76.16	76.17
cmc	**62.91**	51.39	42.70
Dermatology	68.12	**96.17**	49.73
diabetes	**78.43**	72.91	67.20
Glass	**64.15**	60.74	35.52
Hapititus	**89.25**	80.64	76.75
heart-c	**85.43**	82.83	68.42
Heart-h	**83.43**	82.99	66.63
Ionosphere	75.55	**90.02**	61.83
labor	**89.44**	87.71	79.00
Mushroom	85.23	**98.42**	88.68
page-blocks	**96.31**	90.13	90.08
w-breast	96.29	**96.99**	89.69
Wine	**76.68**	36.51	23.04

B. Accuracy Comparison of ACA with Rules and Tree based Classifiers

This section discusses the accuracy comparison of ACA with Tree and Rules based classifiers. There are total 7 classifiers from both categories i.e. Ripper, PART, J48, BFTree, CART, Decision Table, and ZeroR. The comparison is provided with individual groups of dataset as mentioned in Section VII. The following sub sections explains the results in details.

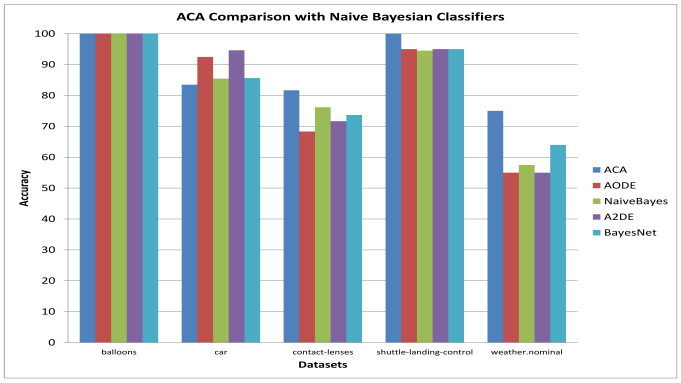

Fig. 11. Accuracy Comparison with Naive Bayesian Classifier over large discrete datasets

1) Comparison with Small Discrete datasets: Table XIII show the results of ACA and other tree based and rules based algorithms. The accuracy of ACA is higher in four datasets while in car, the accuracy goes down. The reason is the The Average Accuracy of ACA is again higher than all Tree and Rules based classifiers.

2) Comparison with Small Continuous datasets: Table XIV show the results of ACA with other tree based and rules based classifier for small continuous datasets. Except the weather-numeric dataset where ACA slightly performed low, in the rest of seven datasets, its accuracy is better. The reason for weather numeric dataset is the number of fewer rules during model construction.

3) Comparison with Large Discrete datasets: The comparison of ACA with tree based and rules based classifiers is shown in Table XV. In large discrete dataset the ACA out performs in three datasets, namely, Breast Cancer, Postoperative Patient Data, Primary Tumor, and Tic Tac Toe. The reason for low performance in vote and zoo is its excessive number of contradictory rules. This high number of contradictory rules results in deceived classifier models. This is the main reason that no single classifier could perform better for these datasets.

4) Comparison with Large Continuous datasets: Table XVI show the results of ACA with other classifiers for Large Continuous datasets. In this category the performance of ACA

TABLE XIII. ACA COMPARISON WITH RULES AND TREE BASED CLASSIFIERS OVER SMALL DISCRETE DATASETS

Dataset Name	ACA	Ripper	PART	J48	BFTree	CART	DecisionTable	ZeroR
balloons	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	60.00
car	83.49	86.46	95.77	92.36	97.05	**97.11**	91.03	70.02
contact-lenses	**81.67**	75.00	**81.67**	**81.67**	78.33	78.33	75.00	68.33
shuttle-landing-control	**100.00**	95.00	95.00	95.00	95.00	95.00	95.00	95.00
weather.nominal	**75.00**	70.00	60.00	55.00	55.00	40.00	40.00	70.00

TABLE XIV. ACA COMPARISON WITH RULES AND TREE BASED CLASSIFIERS OVER SMALL CONTINUOUS DATASETS

Dataset Name	ACA	Ripper	PART	J48	BFTree	CART	DecisionTable	ZeroR
balance-scale	**80.11**	70.55	77.27	64.48	79.2	78.57	66.74	45.76
data_banknote	**98.86**	96.14	97.16	98.40	98.83	98.76	97.38	55.54
hayes-roth	**89.57**	82.53	74.12	72.69	79.51	83.3	47.03	37.91
iris	**96.67**	93.33	95.33	96.00	96.00	96.00	96.00	33.33
iris2D	**98.67**	93.33	92.67	96.00	95.33	96.00	96.00	33.33
liver-disorders	**71.43**	59.39	62.36	61.15	59.44	60.61	62.05	57.98
tae	**69.67**	56.29	47.04	49.71	52.96	54.96	52.21	34.42
weather-numeric	60.00	50.00	55.00	55.00	65.00	50.00	60.00	70.00

TABLE XV. ACA COMPARISON WITH RULES AND TREE BASED CLASSIFIERS OVER LARGE DISCRETE DATASETS

Dataset Name	ACA	Ripper	PART	J48	BFTree	CART	DecisionTable	ZeroR
breast-cancer	**89.66**	70.95	71.33	75.54	67.86	69.26	73.47	70.30
nursery	86.79	96.84	99.21	97.05	99.49	**99.58**	94.7	33.33
postoperative-patient-dat	**73.50**	71.11	61.11	70.00	68.89	71.11	68.56	71.11
primary-tumor	**54.41**	39.24	40.70	39.80	39.80	40.96	38.91	24.78
tic-tac-toe	88.01	**97.81**	94.26	84.55	93.73	92.90	73.39	65.34
vote	68.47	95.41	94.71	**96.33**	95.40	95.42	94.73	61.38
zoo	86.10	89.00	**93.18**	93.06	91.08	90.09	86.00	40.55

is reasonably good where it out perform all other classifiers in ten datasets out of fourteen. The reason for higher accuracy is the larger number of automata that enable the classifier to accurately classify the class labels.

C. Accuracy Comparison of ACA with Naive Bayesian

The ACA Comparison with Naive Bayes Classifier is performed in this section. Naive Bayes classifier are the most prominent classifiers and work well with dataset with low or zero independence. Classifiers in this groups are NaiveBayes, BayesNet, AODE and A2DE. The following subsections elaborate the results in detail.

1) Comparison with Small Discrete datasets: Table XVII and Fig. 11 show the results of ACA and other Naive Bayesian classifiers. The accuracy of ACA is higher in four datasets while the average accuracy is above all classifiers in this category.

2) Comparison with Small Continuous datasets: Table XVIII and Fig. 12 represent the results of ACA and Naive Bayesian classifiers for small continuous datasets. The ACA outperformed all Naive Bayesian classifier in seven datasets while on balance scale dataset the NaiveBayes perform better. The average accuracy of ACA is 88.03 which highest among all classifiers.

TABLE XVI. ACA COMPARISON WITH RULES AND TREE BASED CLASSIFIERS OVER LARGE CONTINUOUS DATASETS

Dataset Name	ACA	Ripper	PART	J48	BFTree	CART	DecisionTable	ZeroR
Anneal	79.92	99.00	99.00	98.66	98.77	**98.88**	97.66	76.17
cmc	**62.91**	48.34	47.99	49.29	52.35	53.77	49.76	42.70
Dermatology	68.12	89.32	**94.80**	94.00	94.00	94.00	86.87	30.60
diabetes	**78.43**	72.79	73.44	73.83	71.23	73.97	72.40	65.11
Glass	**64.15**	48.14	60.80	57.92	62.16	60.30	48.53	35.52
Hapititus	**89.25**	80.00	86.46	81.25	78.00	79.33	81.13	79.37
heart-c	**85.43**	80.17	81.84	79.18	78.20	80.81	74.90	54.45
Heart-h	**83.43**	79.28	80.34	80.02	76.93	76.23	81.00	63.95
Ionosphere	75.55	89.18	87.19	86.62	89.19	**89.76**	84.90	64.10
labor	**89.44**	85.00	66.00	57.33	72.67	68.67	65.00	64.67
Mushroom	85.23	**100.00**	**100.00**	**100.00**	99.94	99.94	**100.00**	51.80
page-blocks	**96.31**	93.92	92.71	92.87	94.06	94.08	92.34	89.77
w-breast	**96.29**	94.13	94.28	94.42	93.56	93.42	92.85	65.52
Wine	**76.68**	30.85	32.55	32.65	32.03	29.84	30.92	23.04

TABLE XVII. ACA COMPARISON WITH NAIVE BAYESIAN CLASSIFIERS OVER SMALL DISCRETE DATASETS

Dataset Name	ACA	AODE	NaiveBayes	A2DE	BayesNet
balloons	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
car	83.49		85.46	**94.62**	85.61
contact-lenses	**81.67**	68.33	76.17	71.67	73.67
shuttle-landing-control	**100.00**	95.00	94.50	95.00	95.00
weather.nominal	**75.00**	55.00	57.50	55.00	64.00

TABLE XVIII. ACA COMPARISON WITH NAIVE BAYESIAN CLASSIFIERS OVER SMALL CONTINUOUS DATASETS

Dataset Name	ACA	AODE	NaiveBayes	A2DE	BayesNet
balance-scale	80.11	89.45	**91.44**	82.24	91.44
data_banknote	**98.86**	97.01	89.60	98.69	89.63
hayes-roth	**89.57**	76.48	82.59	68.96	82.66
iris	**96.67**	94.67	94.33	94.00	94.33
iris2D	**98.67**	96.67	96.87	96.67	96.87
liver-disorders	**71.43**	64.10	64.15	63.5	64.07
tae	**69.67**	56.21	54.25	58.88	54.52
weather-numeric	**60.00**	40.00	56.00	45.00	45.50

3) Comparison with Large Discrete datasets: Table XIX and Fig. 13 highlights the results of ACA with all Naive Bayesian classifier over large continuous datasets. Although ACA outperformed in only three datasets but on average accuracy, it is better than other.

4) Comparison with Large Continuous datasets: Table XX and Fig. 14 show the results of ACA with Naive Bayesian classifiers over large continuous datasets. In this category, ACA beaten all classifiers on eight datasets while AODE and BayesNet the accuracy on two datasets are higher while A2DE and NaiveBayes outperformed in one dataset each. The ACA is using a larger collection of rules,due to large datasets, that results in higher accuracy. The average accuracy of ACA is higher than all classifiers in this category.

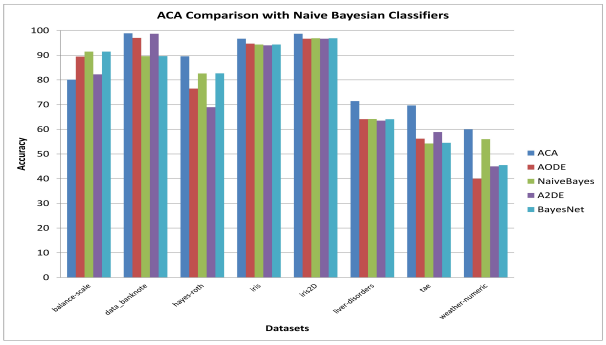

Fig. 12. Accuracy Comparison with Naive Bayesian Classifier over large discrete datasets

TABLE XIX. ACA COMPARISON WITH BAYESIAN CLASSIFIERS OVER LARGE DISCRETE DATASETS

Dataset Name	ACA	AODE	NaiveBayes	A2DE	BayesNet
breast-cancer	**89.66**	71.03	72.70	72.46	72.59
nursery	86.79	92.72	90.30	**94.83**	90.31
postoperative-patient-dat	**73.50**	64.78	68.11	64.78	65.89
primary-tumor	**54.41**	49.53	49.71	49.62	47.11
tic-tac-toe	88.01	72.96	69.64	90.71	69.59
vote	68.47	94.30	90.02	94.30	90.23
zoo	86.10	96.00	93.42	97.00	93.52

X. COMPLEXITY ANALYSIS OF ACA

This section provides the computational analysis regarding time and space requirement of the algorithm. Analysis shows that ACA is reasonably efficient. The subsections explain time and space complexities individually.

A. Time Complexity Analysis

ACA consists of two algorithms i.e. *FA Construction* and *Classifier*. The complexity of both algorithms are explained in the subsequent section.

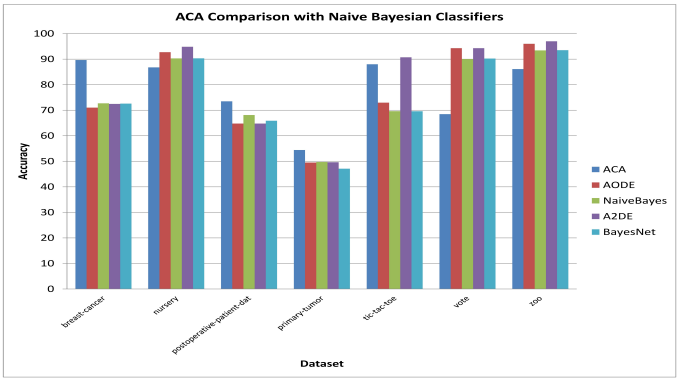

Fig. 13. Accuracy Comparison with Bayesian Classifier over large discrete datasets

TABLE XX. ACA COMPARISON WITH BAYESIAN BASED CLASSIFIERS OVER LARGE CONTINUOUS DATASETS

Dataset Name	ACA	AODE	NaiveBayes	A2DE	BayesNet
Anneal	79.92	95.21	94.56	95.1	94.31
cmc	**62.91**	53.02	50.74	52.40	50.78
Dermatology	68.12	97.81	97.46	96.99	97.79
diabetes	**78.43**	76.96	75.68	74.75	75.57
Glass	**64.15**	59.42	57.69	60.78	58.48
Hapititus	**89.25**	85.13	84.31	83.87	83.91
heart-c	**85.43**	83.47	83.38	82.16	83.55
Heart-h	**83.43**	78.92	83.01	76.18	83.01
Ionosphere	75.55	92.88	90.86	92.60	90.86
labor	89.44	83.00	92.70	83.00	95.07
Mushroom	85.23	99.98	95.76	100.00	96.22
page-blocks	**96.31**	93.42	94.32	93.68	94.67
w-breast	96.29	96.71	97.30	96.99	97.30
Wine	**76.68**	32.68	38.56	33.66	36.92

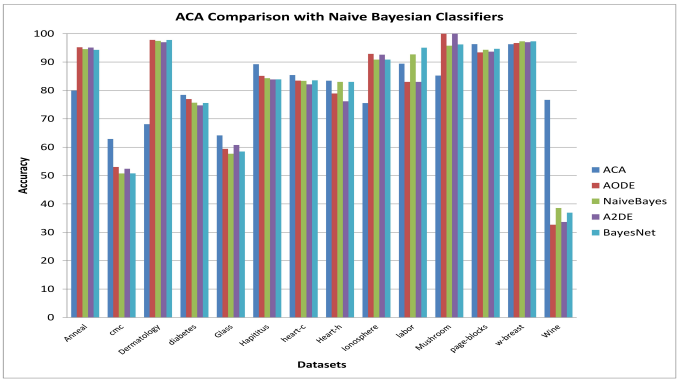

Fig. 14. Accuracy Comparison with Bayesian Classifier over large discrete datasets

1) Analysis of FA Construction Algorithm:: The running time of FA_Construction is equal to the number of transitions from one state to another. If we have n attributes, and there is "forward only" transition to every state from the current state, then the possible numbers of required transitions are $m \rightarrow (m-1)$, $(m-1) \rightarrow (m-2)$, ... , $3 \rightarrow 2$, $2 \rightarrow 1$ (from attribute i, there are i - 1 possible transitions with forward only restriction). For example, if a rule set consists of three attributes A,B,C in a chronological order, then there are two possible transitions from state A, (one to B and one to C) and one move from B to C. Therefore, generally the total number of transitions are

$$\sum_{i=1}^{m} \sum_{j=i}^{m} j \tag{8}$$

which is $O\left(\frac{m^2}{2}\right)$in the worst case scenario and $\Omega(m)$ in the best case. If there are n rules in a rule set, the total time will become $O\left(n\left(\frac{m^2}{2}\right)\right)$. In ACA, single transition can have multiple labels from input symbols, therefore the number of labels is not considered. The hardest part of this module is conflict resolution. Theoretically, if every rule is causing conflict at final state, then the algorithm may be $O(nm^2)^2$. The reason is that, in each of the iterations, only one rule becomes a new automaton and all the remaining rules are checked against the newly-created automaton.

2) Analysis of Classifier Algorithm:: It is assumed that there are j Automata with k states in every automaton. Following this, the classifier, in the best case scenario, will take only $\Omega(k)$ time when the first automaton classifies the test instance. In the worst case scenario, if the algorithm is unable to classify the instance at all, then the time will be $O(jk)$ for a single instance. For a whole test dataset with r number of rules, the running time will be $O(rjk)$and $\Omega(rk)$. Hence, the total running time of ACA is the summation of $O(nm^2)^2 + O(jk)$ in worst case while the best case is the sum of $\Omega(nm^2) + \Omega(jk)$ which is much smaller than most of the pruning and ranking algorithms.

B. Space Complexity Analysis

The space requirement depends on, specifically: a) the number of attributes, b) cardinality of attributes (i.e. distinct values of attributes which is called input symbols in ACA), and c) number of rules in CARs. Input symbols of the automata consist of the unique values of all attributes; so if there are three attributes A_1, A_2 and A_3 with 7, 8, 9 distinct values respectively, the size of the input symbol will be 24 $(7 + 8 + 9 = 24)$. If the attributes' values is transformed to consecutive integers such that every attribute's value starts from 0. Using this approach the language size will reduce to the cardinality of the largest attribute; i.e., in the above case the language size will reduce to 9 instead of 24.

Secondly, in the best case scenario, if all rules are absorbed in a single automaton then the space is $O(\alpha m)$ where α refers to the number of input symbols and m is the number of attributes. If every rule causes a conflict and creates separate automata, the space requirements will be bounded in $O(r\alpha m)$where r is the total number of rules. Therefore the space requirement is in $\Omega(\alpha m)$ and $O(r\alpha m)$.

XI. Conclusion

In the field of data mining, associative classification has been researched for more than two decades; however, the trade-off between pruning and accuracy is still under research, while the application of automata as a deterministic approach has received little attention. In this research, automata were utilized for two purposes: a) as a storage structure in classification; and b) to replace the rule pruning and rule ranking phases of associative classification. In the former case, the use of automata enabled the classification to deal with enormous datasets by reducing the space requirements for the purpose of classification. In the latter usage, the automata produced a loss-less associative classifier by eliminating the pruning steps that can result in a loss of useful information with unwise pruning. The automata also helped to reduce the size of the dataset by taking advantage of the repetition of data in the dataset. The sequential nature of the automata allowed the absorption of similar data items into a single automaton.

In the process of size reduction and similar data item absorption, automata can generate conflicts. These conflicts can arise from conflicting association rules, which in turn can lead to conflicting classification results. Consequently, these rules were put into separate automata to avoid the conflicts in the first place. Following the different strategies discussed in this paper, these automata can reduce conflicts by avoiding merger, but this results in a large number of automata and in some cases can lead to a larger classifier. Therefore, a new merging concept was developed to merge automata based on their structure-based similarity. This structure-based similarity helped to reduce the classifier size as well as to minimize the chance of a loss of information.

XII. Future Work

It is evident from this research that the use of automata has the potential to improve classification in general. The current approach is able to handle discrete value datasets only, but it can be extended to deal with the numeric data as well. This will increase the scalability of the ACA and will advance in application in additional areas of interest. The ACA can also extend to streaming data classification. One possible application might be for real-time virus and malware detection. Incoming data could be analyzed during its runtime to detect any malicious applications. Automata can also incorporate the probabilistic approach, where they can use the rough-set theory to decide from among overlapping class predictions. One possible application of this approach could be real-time fraud detection, where rough set theory can help to define the boundaries between legitimate and fraudulent transactions.

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Smart Coaching: Enhancing Weightlifting and Preventing Injuries

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***Abstract*—Getting injured is one of the most devastating and dangerous challenges that an athlete can go through and if it is a big injury it could end his/her athletic career. In this paper, we propose a system to automate the idea of coaching an athlete, by using an IR Camera (Microsoft Kinect Xbox 360) to detect the misplaced joints of the athlete while doing the lift, and alerting the athlete before an injury can occur. We are now able to detect if the lift was correct or wrong and to detect what kind of mistake has been done in the lift by the athlete by using the Fast Dynamic time warping (FastDTW) method. The FastDTW method has outperformed other classification methods and can achieve recognition with 100% accuracy for dependent user movements.**

***Keywords*—Weightlifting; joints; KNN; fastDTW; Naive Bayes; SVM; detecting injuries; machine learning; IR camera**

I. Introduction

Weight training is one of the most injuries affecting training methods due to wrong techniques of lifting the weights. Although few systems were developed to analyze some weightlifting exercises, they still need a coach's view to correct the wrong techniques. Weightlifting is the sport of lifting a heavy barbell in various different ways, and it has been an Olympic sport since 1922. The main lifts of Olympic weightlifting are the Snatch and the Clean&Jerk. Those lifts are called complex lifts that consist of several movements attached together to form one whole lift.

Three of those fundamental movements are the Deadlift, the Squat and the Shoulder Press. In the 'Deadlift' as shown in Fig. 1 the athlete just picks up the weighted barbell from the ground. In the 'Squat' as shown in Fig. 2 the athlete sits down and stands up with the barbell on his/her back. The 'Shoulder Press' as shown in Fig. 3 is pressing the barbell from his/her shoulder to overhead.

Each movement has a special pattern that must be done with at least 90% of the Right technique or an injury would occur otherwise [9]. In the Deadlift, the spine has to be straight in one line as shown in Fig. 1(a), if it is rounded as Fig. 1(b), the chance of injuring the lower back is high. In the Squat, back should be straight, knees behind the toes and heels on the floor as shown in Fig. 2(a), if the back is not straight and knees surpass the toes as shown in Fig. 2(b), there is a high risk of injuring the knee joints. In the Shoulder press, the bend in the back must be as limited as possible, if it is too bent as shown in Fig. 3(b), an injury will occur in the back.

Fig. 1. Deadlift: a) Right. b) Wrong.

Fig. 2. Squat: a) Right. b) Wrong.

Fig. 3. Shoulder Press: a) Right. b) Wrong.

Teaching the right techniques of these movements is a task that requires an expert at lifting weights. We present a system that has the ability to coach an athlete at any level to do those movements injury-free.

Preventing injuries and showing the right technique of the

lift remains our core focus. Working on the fundamental lifts in weightlifting can assure right movement patterns and injury-free lifting the two complex lifts that consist of those three lifts we mentioned before.

For example, Fig. 1 shows the difference between the wrong and the right technique of the 'Deadlift'; on the left image, it shows the straight spine while on the right one it shows the bent spine which causes an injury in the back. Most injuries that occur during wrong techniques are joint injuries because the joint is the main connection between all bones. It is vital to detect how the joints move to correct the movement pattern. We utilize the infrared camera for detecting the coordinates of the joints of the athlete while doing the lift, which is then tested and classified according to our training data set.

The training data set consists of joint coordinates extracted from the infrared camera videos taken of coaches and athletes doing the three movements with the right and the wrong techniques.

The infrared camera we are using (IR Camera) reading coordinates are fixed, so if the camera's placement changed from one place to the other, the joint coordinates will not be as accurate. This problem had solved by using skeletal tracking, which is a fixed place that the athlete has to start from, so the joint readings are more accurate.

Several classifiers were tested such as Naive Bayes, KNN and Fast DTW. Classification of such a data set faces many challenges, such as the different number of frames from one video to the other, one athlete may take 3 seconds to complete the full lift and one may take 5 seconds. This problem had solved by employing the FastDTW classifier, as it ignores the speed of the video and classifies according to the sequence of frames.

II. Related Work

Many kinds of research and projects used similar algorithms and equipment in various scopes. Each of them reached different accuracy and numerous results.

A. Coaching

In the past, some research has used a diversion of methods to coach people to improve their performances doing their daily activities.

Xin Jin et al. [7], presented a system based on visual guidance that helps users perform exercises with the right techniques. The system has consist of two phases, the User phase and the Dataset phase which is the analysis phase. Their system used the DTW algorithm to compare the user's techniques to the already stored videos in the database to measure the accuracy. Then it guides the user to fix their technique to meet the standard technique. They used the Kinect to get the positions of the joints of the user's body. They managed to improve the accuracy of the users' performance by 72.98%.

Pradeep Kumar et al. [10], proposed a real-time virtual trainer. That used the Random Forest Classifier to recognize the exercises performed by the users. They prepared their dataset by choosing 5 ideal exercises that can be performed by anyone in daily life, these five exercises were done by 3 different Fitness trainers. Their experiment's outcome was 96% accurate.

Edwin W Trejo et al. [16], presents a system that uses the Ada-Boost algorithm to analyze 10 clips of each of the 6 yoga poses in the dataset. An avatar of the user will change colors according to the rightness of the pose. 94.78% is the accuracy level they reached training people to perfect their yoga poses.

Hua-Tsung Chen et al. [4], used Contour and Skeleton Computation to capture binary maps of the body. Then used Feature Axis Extraction algorithm to extract certain points on the body to measure the correctness of the three Yoga poses. To then assist yogis to improve their postures. They reached an overall accuracy of 98.67%.

Out of all the previous researches, our system has some concepts in common with them and differs in others. For instance (i) The use of the Kinect in virtual training. (ii) We used the DTW algorithm. (iii) We target workout and fitness exercises.

B. Weightlifting

Many applications and projects recently appeared to help their users with their workout but very few can guide the user with their Weightlifting techniques.

Pichamon Srisen et al. [15], worked on detecting the 20 main joints in the human body that are involved in weightlifting. To do that they used the infrared camera (Kinect) and the Lucas-Kanade optical flow algorithm. Their accuracy reached 80.5% for hands, feet and knees.

Anargyros Chatzitofis et al. [3], created a weightlifting electronic assistant. Using the infrared camera (Kinect) to detect the human structure. They calculated: i) The Weightlifting Bar Position. ii) The Weightlifting Bar Angle. iii) The Weightlifting Bar Velocity. iv) The Knee Angle Calculation.

Abdul Monem S Rahma et al. [13], proposed an analysis system that monitors weightlifters performing the Snatch and Clean&Jerk moves. Using the Correlation algorithm they managed to get to 75% accuracy.

Perfecting the accuracy of the lift, minimizing the chances of injury and facilitating the training techniques are things we have worked to improve in our system.

C. Camera based Techniques

In trying to make the electronic training or coaching concept more approachable for works, the human started to add the virtual aspect using various virtual aiding technologies.

Orasa Patsadu et al. [12], used an infrared camera (Kinect) to recognized different gesture patterns. they started to test on an individual video for different six human bodies and gender. They used a different data mining classification algorithms to recognize those gestures parent in their videos and to classify them, such as Back-Propagation Neural Network (BPNN), Support Vector Machine (SVM), Decision Tree, and Naive Bayes. Only two of those algorithms showed the highest accuracy. These two algorithms are the SVM which showed 99.75% accuracy and the Naive Bayes showed 81.94% accuracy.

Frederik Wieh et al. [17], used an infrared camera (Kinect 2) to recognize the skeleton of the climber doing a successful ascent.

Sai Prakash Reddy Gaddam et al. [6], used an infrared camera (Kinect 2), Vicon Cameras and Force Plates to compare the force the human's Jumps. The results collected from the Kinect were close to those collected from the Force Plates.

Sean Clarkson et al. [5], used four infrared cameras (Kinect) to mount their test objects. They used those cameras to take shots of four different sized cylinders in different positions multiple times. To compare between the output and the ISO standards. The third and fourth cylinders met the ISO 20685-1 requirement standard with large girth and confidence of 95%.

As part of our system, we used one infrared camera (Kinect) to capture the athlete performing the lift. To cluster and classify them as those lifts were there are the right techniques or detect as the wrong techniques which may cause injuries for the athletes.

D. Classifiers

In order to run tests on the visual data collected from the IR Camera and other visual sensors, some research started to use a wide number of classifiers such as KNN, SVM, GMM, DTW, etc.

Alina Delia Calin et al. [2], proposes a system that uses multiple IR cameras as (Kinect 1 and Kinect 2) to capture poses and gestures. The system tested 41 classifiers such as Simple Logistic, Multilayer Perceptron, Random Forest and Naive Bayes. Then combined all obtained results from the Kinect 2 data sets and the ones collected from Kinect 1 to compare classifiers' performances. She compared the time, accuracy and precision to build the models. Some of the highest accuracy results she reached are for the Multilayer Perceptron algorithm scored accuracy: 99.08%, precision: 99.1%, Random Forest scored accuracy 98.957%, precision 99%.

Sowmya Kasturi et al. [8], used the support vector machine (SVM) to detect and classify which action was a fall and which was done deliberately. Their method showed a total training accuracy of 99.7% and a total testing accuracy of 96.3%.

Lichao Zhan et al. [19], they presented the development of a single-user adaptive scoring system for Golf Swing by using an infrared camera (Kinect). They used the support vector machine (SVM) and Gaussian Mixture Model (GMM) to classify and cluster the swing. Their system improved the accuracy of Golf Swing recognition by 84.1%.

Manus Ross et al. [14], used an IR Camera (Kinect) and the RGB-D sensor to detect, monitor, count and record student gestures, postures, facial expressions, and verbalizations in order to produce data for determining student attentiveness. The data collected is clustered into two clusters using the K-means algorithm. The SVM was then used to classify the clustered data to establish decision boundaries.

Yi-Hua Zhou et al. [20], used the support vector machine (SVM) classifier to classify the shot type from a football video. They also used GMM to remove the grass from the video and HSV for the color distribution. For the edge distribution, they used the canny operator where they proposed that had high detection performance. The average precision that they attain is 92%.

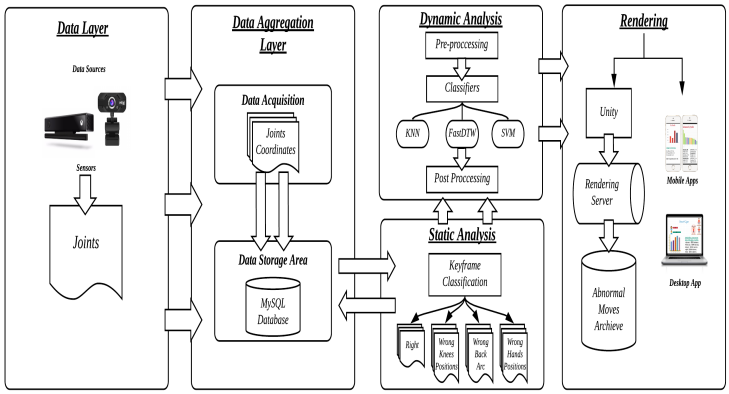

Fig. 4. The System's Block Diagram.

Choubik Youness et al. [18], used an IR Camera (Kinect) to detect the human skeleton to classify the human poses. They used the support vector machine (SVM), artificial neural networks (ANN), k-nearest neighbors (KNN) and Bayes classifier (BC). They tested 100 examples for each pose. They reach the accuracy to 100% in each classifier but with different amount of training data that they tested. For the support vector machine (SVM), the Linear Kernel needed 44%, the Polynomial Kernel needed 66% and the RBF Kernel needed 55%. For the artificial neural networks (ANN), they used for the Sigmoid and Gaussian function needed 44%. For the k-nearest neighbors (KNN), they needed 66%. But for the Bayes classifier (BC) it was the highs accuracy reach is 99.9% at 88% of the train data.

In our system, we have tested some of the previously mentioned algorithms such as the SVM, FastDTW, Naive Bayes, KNN and the Random Forest. Different algorithms have given various results.

III. Methodology

A. Pre-Processing

First, the system used the IR camera and the Camera to capture the Lift. The IR Camera detected 20 Joint from the human body as shown in Fig. 5. These joints are put in front of the athlete on a screen. We worked on Shoulder Press, Deadlift and Squat style. For Shoulder press, we detected six joints in the athlete's body which are Wrist Left, Wrist Right, Shoulder Left, Shoulder Right, Center Shoulder, and Spine as shown in Fig. 5. For Deadlift and Squat, we detected six joints in the athlete's body which are Knee Left, Knee Right, Shoulder Left, Shoulder Right, Center Shoulder, and Spine as shown in Fig. 5.

The IR Camera was used to get the X, Y, Z coordinates of each joint, that has been detected for each movement. And the

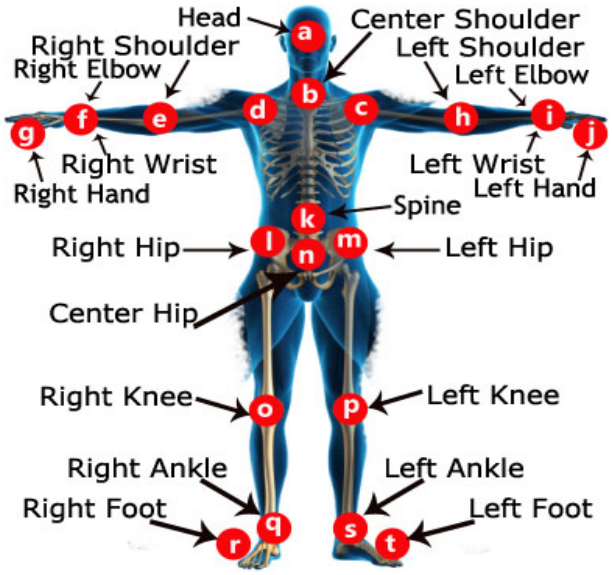

Fig. 5. The Joints that detected by the IR Camera.

Camera recorded the whole lift. It was put on either side of the athlete. Then, the data received from the IR Camera and the Camera were stored in our data storage as shown in the block diagram (Fig. 4).

B. Classifiers

In this phase, the system used different classifiers to detect the result of the last lift. FastDTW was used to classify the lift as right or wrong. The System then allows the coach to choose the most accurate of the recently classified lift to be added to the template data from the data storage.

1) The k-nearest neighbors(KNN): The k-nearest neighbors are one of the oldest and simplest methods of classification. The idea behind the KNN algorithm is quite simple. Given the video of the last lift to get the coordinates of each joint that has been detected for each movement.

And set of all the videos that have the coordinates of each joint in our data set and their labeled neighbors from the data storage in the template table. The task of the classifier is to predict the video's class label based on the class labels in the set. Using the 5 nearest neighbors using the majority vote by the Euclidean Distance as shown in equation (1) [1].

$$d(p,q) = d(q,p) = \sqrt{(q_1-p_1)^2+(q_2-p_2)^2+...+(q_n-p_n)^2} = \sqrt{\sum_{i=1}^{n}(q_i-p_i)^2} \quad (1)$$

p: points of tested video, q: points of each video from dataset.

2) Fast Dynamic Time Warping (FastDTW): Time series analysis, dynamic time warping (DTW) is one of the most used algorithms for measuring the similarity between two temporal sequences for the same action but different in time and speed. It has been designed especially for time series analysis, because it helps to ignore Shifts in the time dimension, ignore Speeds of two-time series.

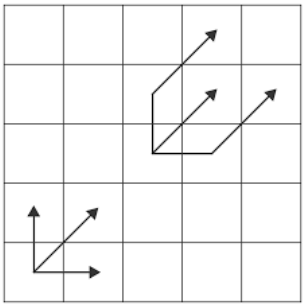

Fig. 6. Creating Cost Matrix.

First, the FastDTW start to create a cost matrix between the test lift's coordinates of the athlete body and each video in the data set.

$$Dist(I,J) = Dist(I,J) + min\begin{cases} \text{Dist(I+1,J)} \\ \text{Dist(I,J+1)} \\ \text{Dist(I+1,J+1)} \end{cases} \quad (2)$$

I:tested lift points, J: one lifts points from data set

FastDTW starts to create each point in the matrix that between the test lift points and each lift points in the data set, by getting the minimum value between the two points and the minimum of its neighbors as shown in Fig. 6.

Second, the FastDTW uses backtracking & greedy search in the cost matrix to get the distance between the two lifts.

$$Dist(W) = \sum_{K=1}^{K=L} Dist(\quad W_{KI}, \quad W_{KJ}) \quad (3)$$

L: Last left point in the cost matrix, W: the cost matrix, K: each cell in the matrix

FastDTW starts to get the distance between the two lifts, by adding the point from the top left of the cost matrix cell. Then go to get the minimum of its neighbors until it reaches the first cell of the matrix.

In the end, after getting the distance between each lift in the data set and the tested video. It starts to get the minimum one of them to get the label of the lift from the data set to be labeled the lift as it been classified.

3) Support Vector Machine (SVM): Support Vector Machines (SVM) uses supervised learning data. Its basic idea is to find an optimal hyperplane margin that properly separates data by choosing a vector from each set. Keeping in consideration that has to be the furthest away as possible from all data. SVM categorizes each group of videos by their labels grouping them

Fig. 7. The System overview.

together. It then starts calculating the new video's distance to define which class it belongs to.

$$F = [J_{1x}, J_{1y}, J_{1z}, J_{2x}, J_{2y}, J_{2z}, J_{3x}, J_{3y}, J_{3z}].$$
$$L = [F_1, F_2, F_3, ...F_n].$$
$$R = \sqrt{(qF_1 - pF_1)^2 + (qF_2 - pF_2)^2 + ... + (qF_n - pF_n)^2} \quad (4)$$

J: Joint, F: Frame, L: Lift, R: Result, q: Test Lift & p: from data set.

So, our vector that we used in SVM is the X, Y, Z coordinates of each joint in each frame of the video. Then, it starts to compare each position of each joint in each frame in the lift and each video in the data set. In the end, it seems the nearest video labels to get the result.

C. Post-Processing

Finally, our system lets coach choose which of the newly classified videos is accurate enough to be added in the template table. To start building a machine learning sequence that allows the system to improve the results.

IV. Experimental Setup

The IR Camera was placed on a box with height, 47 cm and the athlete is standing away from it with a distance between (2.90cm -2.95 cm) as shown in Fig. 7. There, ware 10 athletes, all were males, aged between 20 to 30 doing the Shoulder Press movement, deadlift, and squad. The aim of the experiment is to test different algorithms for classification of movements (user dependent and user independent), respectively. Our experiment has been done in Professional Gym.

A. User Dependent Experiment

A senior coach has been asked to be a subject for our experiment, and he had to build his own training data set, he has to record the lift 10 times per each class. After that, we have asked 1 athlete to test all the three movements for nine times. here are the results are shown in Table I.

TABLE I. Results of the User Dependent Experiment on the Three Movements

Movement	FastDTW	KNN	SVM	Naive Bayes
Shoulder Press	100%	77.78%	88.89%	66.67%
Deadlift	100%	100%	100%	88.89%
Squats	100%	66.67%	77.78%	66.67%

TABLE II. Results of the User Independent Experiment on the Three Movements

Movement	FastDTW	KNN	SVM	Naive Bayes
Shoulder Press	91%	86%	70%	68%
Deadlift	100%	100%	93%	87%
Squats	98%	60%	40%	56%

B. User Independent Experiment

A senior coach and two beginner athletes have been asked to be a subject for our second experiment, they have to record their lift 15 times per each movement. then we start classifier each lift by using different algorithms and here is the results shown in Table II.

FastDTW has shown the best accuracy compared to KNN, SVM and Naive base with an accuracy of 100%. FastDTW shows the highest accuracy because it almost works with different time series analysis to measuring the similarity between two temporal sequences for the same action but different in time and speed. The naive base has shown the worst accuracy, based on Lindsay et al. [11] presented that Naive base algorithm shows low accuracy with time series analysis, due to Naive Bayes learner invalidly assumes independence of attributes of the lift.

V. Conclusion and Future Work

We present a system that automates the process of coaching an athlete through the fundamental lifts which are: the Squat, the Deadlift and the Shoulder Press. Decreasing the injuries that occur due to these three movements is the main focus. In future work, the scope of the system could grow by adding more movements in weightlifting sport. Our future work, to add more different movement in weightlifting, and the wrong moves that bring different injuries for the athletes. Also to normalize the dataset to avoid the 2.90cm range that has been used in this paper.

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