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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!

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Editorial Board

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Hybrid Multi-faceted Computational Trust Model for Online Social Network (OSN)

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***Abstract*—Online Social Network (OSN) is an online social platform that enables people to exchange information, get in touch with family members or friends, and also helps as a marketing tool. However, OSN suffers from various security and privacy issues. Trust, fundamentally, is made up of security with hard trust (cryptographic mechanism) and soft trust (recommender system); user's trustworthiness for this platform has decrement signed. In this paper, the authors leverage the multi-faceted model trust concept from user-centric and personalized trust model and present weightage and ranking for its important features by employing statistical means. Next, the multi-faceted model trust is combined with an existing Action-based model and Context recommender. The contributions of this research are an enhanced trust algorithm and an enhanced context-based, recommender-based trust, which has been tested based on user-acceptance. Overall, the result demonstrates OSN as fairly better by employing a multi-faceted model which embeds both actions incomparable to recommender type.**

Keywords—Multi-facet Trust; Recommender Trust Model; Action Trust; Online Social Network; Security

I. Introduction

In recent years, online social networks (OSNs) have attracted millions of users worldwide and become part of their daily life. Websites such like LinkdedIn, Twitter, Google+ and Facebook which have been built on social networks are among popular OSNs with millions of users visiting them daily. The purpose of an OSN is, among others, for exchanging personal information, opinion, photographs, building friendships across borders, and as a tool for business advancement and marketing Nevertheless, OSN sites have flaws related to privacy and security leading to untrustworthiness in this technology [1, 12, 23, 24]. There are unprotected user profiles in OSNs which contain high amount of personal information, and therefore, privacy attack such as location and data privacy stands as a major threat of information leakage. Information leakage of user's lifestyle and linkability between various bits of information such as location, time, user-identity and data threaten the well-being of a user in terms of safety [2]. Furthermore, privacy is an important problem within OSN sites, particularly when a genuine OSN user identity and account can be easily accessed publicly via other search engines by simply using the index his/her profile. In short, there is no certainty of user trustworthiness towards the OSN technology which leads to the aim of the paper which is to study in depth the non-trivial trust persona.

In theory, trust refers to the willingness of a party to go through risk taking and to reduce doubt to the lowest degree of confidence [1,3,4]. Trust is fundamentally based on experiences [1,4] and the ability to provide annotations of trust with confidence and without constraint. In the area of computer science, a lot of studies have been conducted revolving trust management, computational algorithms, and trust models. Various trust models in multiple domain have been proposed such as User-Centric Personalized Trust model, TISoN, regret, and Spares and Marsh's trust model. [1, 5, 6].

This research will adopt the trust concept of Quinn's multi-faceted model to capture the subjective view and meaning of trust across large populations in OSN. Trust synonyms selected as the trust concept in the core of Quinn's model are honesty, faith, belief, confidence, competency, credibility, reputation, and reliability. This multi-faceted trust model was found successful for users in the application of OSNs. Chieng, *et al.* [1, 23, 24] findings show the user acceptance of this model through the usage of a prototype namely MiniOSN. However; the findings, which were based on data gathering and analysis of survey suffer from flaws due to the imbalance and undefined trust features accordingly. The core of Quinn's [12] model is honesty, faith, belief, confidence, competency, credibility, reputation and reliability. However; the representation and ranking of these features is yet to be determined. There are no indication or ranks of importance for these attributes listed in multi-faceted model. For instance, in the context of trust, the attributes of confidence should be more important than belief attributes. Non-ranking attributes are reflected in the reliability of the overall trust model.

Hence, this research includes three main objectives: i) to provide descriptive reasoning by determining the ranking of importance for each trust attribute of multi-faceted model[1] statistically; ii) to propose Enhanced Action-based Trust (EABT) algorithm and Enhanced Multi-Facet Trust with Context Recommender Mathematical Model (EMF –CRMM) as computational trust models that input the weightage obtained in objective ; and iii) to evaluate and benchmark both trust computational model techniques implicitly and intrinsically. Enhanced Action-based Trust (EABT) algorithm is the outcome of the author's Multi-faceted trust model with an existing computational algorithm [9].Enhanced Multi-Facet Trust with Context Recommender Mathematical Model (EMF –CRMM) is the outcome of hybrid between the author Multi-facet trust model with an existing computational algorithm [17]. The contribution of this research is to provide a novel means of trust attributes ranking and two hybrid computational based trust which can be employed in the OSN.

The rest of the paper is organized as follows. Section 2 describes the related work. Next, Multi-facet ranking based on correlation is described in Section 3. Section 4 includes the proposed EABT algorithm and its user-acceptance. Section 5 discusses the proposed EMF-CRMM model and the user-acceptances on it. Finally, a section on conclusion and future work is presented.

II. Related Work

In this section, some literature on the related subject will be given.

A. Online Social Networks (OSNs)

According to Boyd and Allison [7], the key elements of any OSNs are allowing individuals to construct a public or semi-public profile within the service, to articulate a list of other users with whom they share a connection and to view and traverse their list of connections and those made by others within the service. In 1997 [8], the first OSN was SixDegrees which allowed users to create profiles, list and message their friends and traverse friends listing, thus suiting the definition of an OSN defined by Boyd and Allison. Besides messaging, SixDegrees did not provide other functionality, hence, it finally shut down in 2000 [8]. Currently, OSNs sites offer wide functionality beyond simply listing and browsing friends. Contemporary OSNs like Facebook, LinkedIn, and Twitter besides allowing users to create a network to represent their social ties, also facilitate uploading of multimedia content, various ways of communication, and allow many users to share aspects of daily life with friends. As users share these private content, they must trust the OSNs service to protect their personal information. The main target in a social network is to enjoy the benefits of social networks while mitigating the security issues. However, benefits aside, the potential privacy risks or threats to user of OSNs are often underestimated or ignored [8]. Some of these personal information would not be valuable by itself, but having a clear picture of everything about a person can give attacker ideas and information required to perform others attacks such as credit card fraud or identity theft. Although security standards and practices are an increasing subject of attention, participants still reveal great amounts of sensitive information in the Web 2.0 environment. The risks of privacy and security are the concern of a user engaged in OSNs. Hence, online social networking takes place in a context of trust as trust is a very important aspect of human life.

B. Trust Management in current OSNs

OSNs have contributed to substantially increase the interest on trust in this area. Trust has been recognized as the important factor for successful gaining user's heart to use the sites as trustworthiness in OSNs has decreased due to all the security and privacy issues noticed today in OSNs [1]. However, in OSNs, despite all measures taken for privacy and security, there is no certainty of trust in social networks. For protecting their reputation before making decisions, users can consider trust as a very significant information [9]. Trust is also of significance in attracting users to use sites receive recommendations, sort and filter information and develop a context in a community regarding whom to trust and why. In order to ensure the users and make them disclose and share their personal information in sites, a specific level of trust is required. The properties of trust can be examined below [1,12]:

- Asymmetry: As two friends have different belief and may have seen different behavior from each other, so trust is not identical.
- Transitivity: If A trusts B and B trusts G, it does not necessarily follow that A has to trust G.
- Context Dependent: Trust level towards an individual can be varied based on time, situation and experience.
- Personalized: Trust is subjective. One can have different opinions regarding the trust level towards a same person.

Currently, the features below are adopted in the trust model in social networking [1,12]:

Single-faceted:Among many trust concepts, only one of them has been used to explain and define trust and to form a single-faceted model of trust so that it can back trust based on decision making that is too general, while many other significant notions of trust have been neglected.

Not personalized: Trust in the authentic world relies on context and people are not judged by others similarly as the weight of trust traits are different too. Nevertheless, no personalized concept is prevented in the nature of the current trust model. In this concept, subjective nature and the opinions about human's trust toward people in a large population is noticed.

Trust level cannot be annotated and calculated: In the present OSNs, friendship has not been considered in an appropriate category. Therefore, it is not possible to give a good explanation about the trust level towards various people in a context. It is not possible to compute it either. Hence, the trust value on each 'friend' is being uniformity with lists or categories, while it cannot be distinguished based on the percentage of trustiness and the way the user weighted the importance of trust traits.

While reviewing trust management systems in computer science, Quinn, *et al*. [12] found that utilizing only one trust attribute in a single-faceted approach is an inadequate model of trust for use in internet environments. Current trust model "tend to use a single synonym, or definition in the use of trust can only provide a generic, non-personalised trust management solution". To address this problem of the lack of potential for personalizing trust management, a multi-faceted model of trust that is both personalisable and specialisable was proposed by Quinn, *et al.* [12] which can satisfy large and board population. In [12], myTrust Trust Management system defined trust as a concrete concept and abstract concept with the attributes of its own, where the former includes credibility, honesty, reliability, reputation and competency attributes, and the latter includes belief, faith, and confidence attributes. Ratings are then given to each of the eight attributes, and trust is calculated as the weighted average of these ratings. In Figure 1, a number is associated with each of the eight trust concepts, these numbers are referred to as concept weights which based on the algorithm from Kleinberg's 'Hypertext Induced Topic Selection' (HITS) [13].

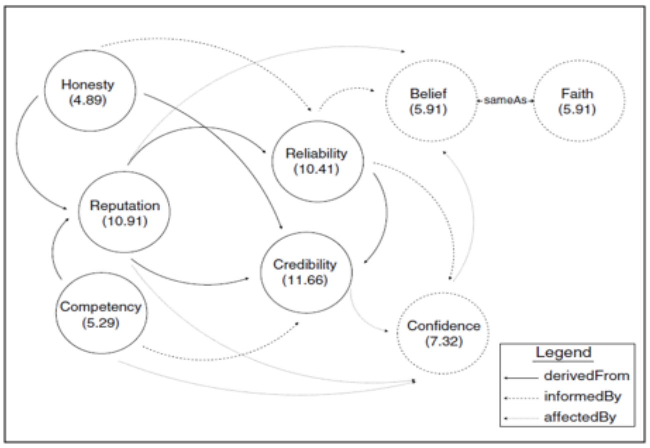


Fig. 1. Illustration of Personalized Model in myTrust [1, 12]

In addition, Quinn, *et al.* [12] work has been extended by Chieng, *et al.* [1] in which the author demonstrates the adoption of Multi-facet model for the application domain of social networks. The ties of the friendship are set according to the eight trusts attributes consist of competency, confidence, credibility, reliability, reputation, faith, honesty and belief. The range of each trust attributes is range from 1 to 10, where the greater the number indicates that the more trust is given to a specify friend. However, there is not a trust value to be computed in this model, and attributes of trust concept might cause some confusion and misunderstanding to the users, the selected of attributes of trust should be defined.

C. Privacy and Security Issues in OSNs

When users collaborate in a Web 2.0 setting, they generally share a lot of personal information which allows users to upload different types of content. A privacy breach occurs when information shared with a party for whom it was not intended, when information is abused for a different purpose than was intended, or when information is accessed after its intended lifetime [8]. One of the most common threats is identity theft or fake identity. When a user becomes the target of an attacker, the attackers are able to collect enough personal information from the person's social network profile to fake his identity or the identity of his contacts. Even a few personal details may provide attackers with enough information to guess the answer to security or password reminder questions for email, credit card, or bank accounts [14].

Unsolicited messages (Spam), cross site scripting (XSS), viruses and worms have capitalized on the exponential growth of OSNs and the free traffic they provide [15]. OSNs are also vulnerable to social engineering techniques which exploit low threshold to trusted networks and to scripting attacks which allow the automated injection of phishing links. On many OSNs, it is even possible to use scripts to invite friends. Attackers who want to have the most impact with the least effort by just creating a virus and embedding it in a website or third party application, then rely on users to share the malicious links with their contacts [16].

D. Computational Trust Models in OSNs

- Online Reputation Models

The reputation mechanism used in most online marketplaces like eBay or Amazon [5] is based on the ratings that users perform after completion of a transaction. The reputation value is computed as the sum of those ratings over the last six months for eBay. Similarly, Amazon [5] also uses a mean of all ratings to assign a reputation value. They do not provide explicit mechanisms to deal with users that provide false information. The only way to increase the reliability of the reputation value is through a tremendous number of opinions that reduce false or biased information.

- Marsh Trust Management [24]

The trust model proposed by Marsh [24] only considered direct interaction. It differentiates three types of trust which are basic trust, general trust, and situational trust.

- Basic trust. Models the general trusting disposition independently of who is the agent that is in front. It is calculated from all the experiences accumulated by the agent. Good experiences lead to a greater disposition to trust, and vice versa. The author uses the notation $Tx\ t$ to represent the trust disposition of agent x at time t.

- General trust. This is the trust that one agent has on another without taking into account any specific situation. It simply represents general trust on the other agent. It is noted as $Tx\ (y)$ representing the general trust that agent x has on agent y at time t.

- Situational trust. This is the amount of trust that one agent has in another taking into account a specific situation. The utility of the situation, its importance and the 'General trust' are the elements considered in order to calculate the 'Situational trust'. The basic formula used to calculate this type of trust is: $Tx\,(y, \propto)\ t = Ux\,(\propto)\ t\,t \times Ix\,(\propto)\ t \times Tx\,(y)\ t\hat{}$ where x is the evaluator, by the target agent and α the situation. $Ux\,(\propto)\ t$ represents the utility x gains from situation α, $Ix\ (\propto)\ t$ is the importance of the situation α for agent x and $Tx\ (y)\ t\ \hat{}$ is the estimate of general trust after taking into account all possible relevant data with respect to tax (y, α) in

TABLE I.

Model Name	Context dependent	Formula of model
eBay [5]	No	N/A
Marsh [24]	Yes	$T_x(y,\alpha)^t = U_x(\alpha)^t \times I_x(\alpha)^t \times \widehat{T_x(y)}^t$
Multi-context trust [11]	Yes	$T_x = \frac{S.T_s + N.T_c + F.T_F + P.T_p + G.T_G + L.T_L}{S+N+C+F+P+G+L}$
TISoN [6]	N/A	For TIM: $t_{o\to s} = s_{MTP} \times t_{a_{nMTP}\to s}$.
Action-based trust[9]	N/A	Shown in Fig 3 and Fig 4.
Trust network based Context Aware recommender system[17]	Yes	$P_{c,i} = \bar{r}_c + \frac{\sum_{p\in M} sim(c,p)(r_{p,i} - \bar{r}_p)}{\sum_{p\in M} \lvert sim(c,p)\rvert}$ $T_{c(p,i)} = 1 - \frac{\lvert P_{c,i} - r_{c,i}\rvert}{z_{MAX} - z_{min}}$ $WT_{(c,i)} = T_{(c,i)}\left[X + Y.\frac{\sum_{q=1}^{m} W_q}{\sum_{q=1}^{r} W_q}\right]$

the past; that is, if t is the current time, x will aggregate all situations $Tx(y, \sigma)\ T$, with $\theta < T < t$ and σ similar or identical to the present situation α. θ and t define the temporal window that the agent is considering. Only the experiences within that window will be taken into account for the aggregation.

- Multi-Context Trust [11]

The mathematical core of this model leans on a theory, distributed by Marsh in his founding thesis [11]. This theory introduces so-called contexts of trust which represent the fields in which the authors are capable of trusting the entity. To explain this term in a simplified example, “I trust my brother to drive me safely to the airport, but I would feel very insecure if he were to go by my plane." Dividing trust into contexts is the only reasonable way to comprise a thing as complex as trust while maintaining the possibility of flexible changes and further development. Every context is normalized into the interval from 0 to 1 to facilitate future aggregation. There are seven different trust contexts stand on functionality provided by Facebook that discussed in [11]. Among the context are i) Interaction time span (S); ii) Number of interactions (N); iii) Number of characters (C); iv) Interaction regularity (F); v) Photo tagging (P); vi) Group membership (G) and vii) Common interests (L).

These seven contexts should be aggregated in a way which allows us to establish an order relation. The equation below is introduced in this model to serve as a priority vector of number where Tx represents the priority for given context.

$$P = (TS, TN, TC, TF, TP, TG, TL)$$

The final value of trust can be calculated with this formula below:

$$Tx = S.Ts + N.TN + C.TC + F.TF + P.Tp + G.TG + L.TL\ S + N + C + F + P + G + L$$

This method of aggregation enables us to attribute each context with its importance. If, for instance, we find a context less contributing to overall trust in our recent findings, we simply decrease the level of importance in the priority vector. Similarly, a completely new context may be added to the existing set and this expansion is also planned in the nearest future in [11].

- TISoN [6]

One of the computational trust models like Trust Inference for Social Networks (TISoN) [6] was introduced a hybrid model which implementation are based on algorithm and mathematical model. Hamdi et.al [6] introduce TISoN model to generate and evaluate trust value helps user and allow them to rate each other without any interactions. [6] designed a novel Trust Path’s Searching(TPS) algorithm to discover the reliable trust path in a large social network then use trust inference measure(TIM) to decide how much the user will trust another. Table 1 demonstrates the computational trust models classification done in OSNs.

- Action-based Trust

In [9], authors proposed a new trust model based on what type of content user disclosure in OSN and what action performed by the user, examples like commenting, liking, sharing a post, and tagging on an image, posting a video and so on. An algorithm is designed to calculate trust values on the basis of the actions performed by the user which lead to users from being aware in sharing sensitive content in OSNs. If the trust value of a user is showing a constant low value over some period of time, then he is suspected to be involved in malicious activities. This algorithm would be amended to consider Quinn multi-faceted trust model in OSN in order to discover an appropriate way to compute the trust.

- Context Aware Recommender Model [17]

Based on the research in [17], Dutta et.al designed a trust based recommender systems leveraged by context attributes, recommender system aims at solving the problem of information flooding and is emerging as a widely used tool for web applications. The recommender system proposed by [17] is a trusted network based context aware recommender system, this type of recommender system takes into considerations trustworthiness of the recommending partners and context information such as time, location and company of a person along with the user and item. According to the author, the accuracy of the recommender output enhanced when the most relevant contexts are selected and their weightages are appropriately taken incorporates with aspects of dynamic trust. In this case, trust is dynamic in nature and not a static parameter. In this research; both Action-based trust and Context-aware recommender model will be adopted and enhanced further. The fundamental of multi-facet trust model with ranked features will be embedded into the enhanced algorithm.

E. Analysis of Quantitative Variables with Correlation Analysis

Mathematically described, correlation quantifies the extent which two quantitative variables, X and Y, "go together"[19]. When high values of X are associated with high values of Y, a positive correlation exists.When high values of X are associated with low values of Y, a negative correlation exits.The resulting value called the "correlation coefficient" shows if changes in one variable or item will result in changes in the other.

When comparing the correlation between two items, one item is called the "dependent" item and the other the "independent" item. The goal is to see if a change in the independent item will result in a change in the dependent item [20]. The strength of the linear association between two numerical variables in a population is determined by the correlation coefficient, ρ, whose range is −1 to +1. A coefficient of +1.0, a "perfect positive correlation," means that changes in the independent item will result in an identical change in the dependent item. A coefficient of -1.0, a "perfect negative correlation," means that changes in the independent item will result in an identical change in the dependent item, but the change will be in the opposite direction.

A low correlation coefficient (e.g., less than ±0. 10) suggests that the relationship between two items is weak or non-existent. A high correlation coefficient (i.e., closer to plus or minus one) indicates that the dependent variable will usually change when the independent variable changes. The direction of the dependent variable's change depends on the sign of the coefficient. If the coefficient is a positive number, then the dependent variable will move in the same direction as the independent variable; if the coefficient is negative, then the dependent variable will move in the opposite direction of the independent variable [20].

III. CORRELATION ANALYSIS FOR TRUST ATTRIBUTES IN MULTI-FACETED MODEL

The sample size for correlation is 83 and the data were collected based on the prototype. When participants sign up an account and login to the proposed prototype known as MiniOSN 2.0 and accept friends request, they are required to edit the friendship which is the trust level with the friends, according to that eight trust attributes, then all the data were stored within the database of the prototype [23]. The data is then extracted from the database to a mathematical tool that help to process the data and to perform the correlation analysis [23]. The result is listed below

TABLE II. Correlation Coefficient of each Trust Attribute [23]

Trust Attribute	Correlation Coefficient
Honesty	+0.76
Competency	+0.81
Confidence	+0.91
Reputation	+0.88
Faith	+0.92
Belief	+0.90
Reliability	+0.86

When comparing the correlation between attribute of trust and value of trust, a high positive coefficient (> +0.70) means a change in the trust attribute will usually predict a change in the trust value. So the higher the values of correlation coefficient, the stronger the strength association between trust value and trust attributes. In Table 2, the value of correlation coefficient of all the trust attributes together with trust value shown very high positive correlation (>0.8). Correlation coefficient for faith is the highest among other trust attributes which is 0.92, followed by confidence and belief which is 0.91 and 0.90. The different of a correlation value between reputation and credibility is merely 0.01 that is 0.88 and 0.87; followed by 0.86 and 0.81 which are reliability and competency. The lowest correlation value among these attributes are honesty which is 0.76. The value of correlation coefficient for all trust attributes with trust value is very close with each other.

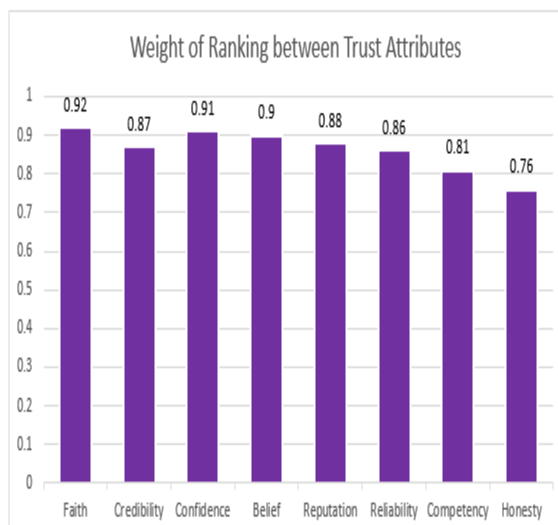


Fig. 2. Ranking of importance among all Trust Attributes

From the result in the Table 2, Chin and Mahinderjit Singh [23] conclude that faith is the most important in multi-faceted model of trust, confidence ranked second important. As seen in Figure 2, the values of coefficients for each attribute are in a symmetric pattern, the coefficient scores of each trust attributes were laid between the scale of 0.76 to 0.92 which show the scores are relatively large and strongly tight between the attributes and overall trust value. Faith is shown the highest coefficient value among all other attributes, for those who responded to this survey, higher trust rated scores were correlated with higher overall trust value scores, are = 0.92, which can be considered a large effect. Without running a test for significance, the authors are not able to infer the same correlation to the rest of the population from which our sample was drawn. From the result of this correlation coefficient, among eight of the trust attributes, faith have the most impact to the users when rating a friend, and followed arranged in an ascending order of ranking, which are confident, belief, reputation, reliability, credibility, reliability, competency and honesty respectively. As in Chieng [1] research work, trust attributes in multi-faceted model as influenced by Quinn [12] considered the wattage for each attributes is equally important in which the wattage are set as the default value. However; the findings of this research demonstrates otherwise. Different attributes have different importance, ranked and weighted.

IV. Proposed Enhanced Action-based Trust (EABT) Algorithm

Action-based Trust algorithm [9] is chosen as it calculates the trust value on the basis of the actions performed by the user which lead to users from being aware in sharing sensitive content in OSNs. Based on the proposed computational algorithm, the value of trust for a user in OSN depends on every each action that he performs for example, like a photo, share, post a status, etc., then compute the value of trust for a user, this value referred as a trust factor by authors in [9]. The trust factor of a user may increase or decrease depending on the category of content the user interacts with, which are classified as sensitive or not sensitive. Gambhir, *et al*. [9] used weight as the measurement for each of the actions the user performs in OSN. *Wa* represents weight for action, and *Wp* represents weight for post; Wc and Pc are weight for category and credibility of a post. *Wa*, *Wp*, *Wc* and *Pc* were taken into consideration as the parameters while computing the trust factor. Table 3 below illustrates the idea of using different weight that simulating the algorithm in different test case scenarios as follows:

TABLE III. Different weightage used in Action-based Trust algorithm

Weight for action, W_a		Weight for post, W_p		Weight for category, W_c	
Share	.008	**Photo**	.003	**Sensitive**	.009
Like	.006	**Video**	.002	**Non-Sensitive**	.001
Comment	.007	**Link**	.001		
Dislike	.006	**Message**	.003		
Tagging	.005				
Post	.008				

Figure 3 shows the Action-based Trust algorithm of computation of trust factor. Here, *Pc* determines whether the message which is to be posted is of right commitment or not. In other words, Post Credibility is the measure of the kind of message which is to be posted. It is used in the calculation of Trust factor only when the action performed is Post (If (Type(*Wa*)==POST)). It is incremented by a factor of .001 if the message being posted is categorized in a non-sensitive category (e.g., academics, music, etc.); and gets decremented by a factor of .009 if the message is categorized in a sensitive category (alcohol, violence, etc.). The existing algorithm is extended and enhanced further by integrating multi-factor trust attributes which has been ranked according to [23].

Algorithm CAL_TRUST_FACTOR (username, password, action, post)
Input: username, password, action, post
Output: Trust Factor of user.
Login from openid

While (true)
{
Calculate Weight for Action (W_a).
Calculate Weight for post (W_p).
If (Type(W_a)==POST) then
{
W_c=0
Call ***Matching_Process (Input, CAL_SEL)***
If (Flag == 0)
Calculate P_c = Old(P_c) + .009; //Every right commitment
Else
Calculate P_c = Old(P_c)-.009; //Every wrong commitment
}
Else
Calculate Weight for category (W_c)
Calculate $E_s = W_p + W_c + W_a$
If (Type(W_a)==POST) then
Calculate Trust factor (T_f) = old (T_f) + P_c + E_s
Else
Calculate Trust factor (T_f) = old (T_f) + E_s
}

Fig. 3. Exisiting Action-based Trust algorithm[9]

Figure 4 below shows the Enhanced Action-based Trust (EABT) Algorithm

Algorithm CAL_TRUST_FACTOR (username, password, action, post)
Input: username, password, action, post
Output: Trust Factor of user.
While (true)
{
Calculate Weight for Action (W_a).
Calculate Weight for post (W_p).
Calculate Weight for catergory (W_c).
// = .001 assume all is non sensitive content
Calculate $E_s = W_p + W_c + W_a$
If (Type(W_a)==POST) then
Calculate Trust factor
(T_f) = old (T_f) + P_c + E_s //assume Pc = .001
Else
Calculate Trust factor (T_f) = old (T_f) + E_s
}

Fig. 4. Enhanced Action-based Trust (EABT) Algorithm

Before computing the trust factor, the seed values of T_f has been compute with the trust rating value given by a user and the weight of trust attributes, also the value is assumed to be up to three decimals place. If seed value is assumed to be integer, the range of the trust factor will get very large which will be very difficult to analyze. Seed value of T_f is calculate as the rating value of a user towards a friend which also another user within same social network site.

$$T_f = \frac{(\text{User's Rating Value}.\sum_{i=1}^{i=8} Weight\ of\ Trust\ Traits)}{8} \quad (1)$$

After T_f is calculated, this value will become the seed value of a user's friend and it also referred as Old (T_f) in the algorithm.

A. Proposed Trust Prototype with Enhanced Action-based Trust (EABT) Algorithm

User will be required to register an account for the proposed Trust Prototype with Enhanced Action-based Trust (EABT) Algorithm; which is known as MiniOSN 2.1. Once the user has registered and signed in into MiniOSN 2.1, he/she requires to confirm the friend request. After friendship being confirmed, the rating value user holds for a friend would be stored into the system database, the rating value of a friend could be varied from time to time based on the subjective views of users, which the authors declared as personalize and context dependent. The higher the value represents the more the feeling of trust express from user to friend. An illustration of these actions is shown in Figures 5 and 6.

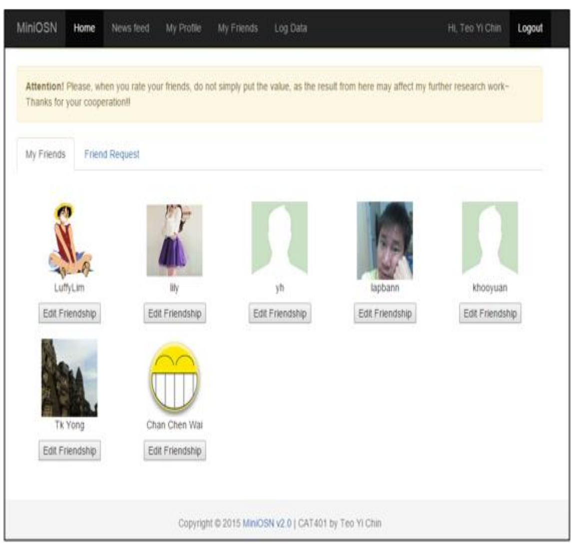


Fig. 5. MiniOSN 2.1's Friend List

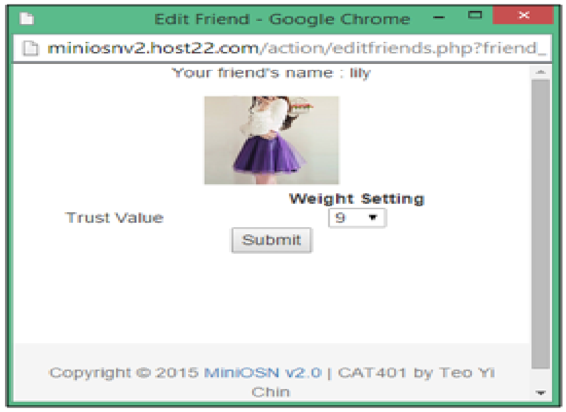
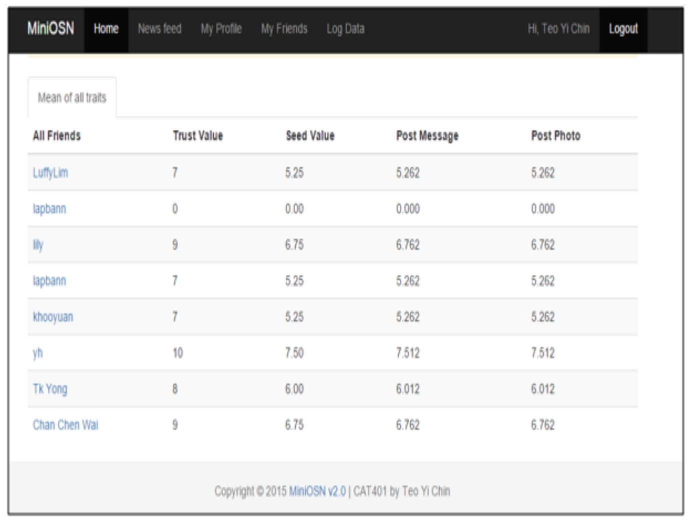


Fig. 6. MiniOSN 2.1's Edit Friendship feature

In Log Data page which is shown in Figure 7, the table displayed on the page showing the result of Trust Value, Seed Value (old (Tf)), Post Message and Post Photo for all the friends of a user, respectively. When the rating value of a friend was assigned by user, system will generate these values automatically based on the enhanced Action-based trust computation algorithm running background in the system.



All Friends	Trust Value	Seed Value	Post Message	Post Photo
LuffyLim	7	5.25	5.262	5.262
lapbann	0	0.00	0.000	0.000
lily	9	6.75	6.762	6.762
lapbann	7	5.25	5.262	5.262
khooyuan	7	5.25	5.262	5.262
yh	10	7.50	7.512	7.512
Tk Yong	8	6.00	6.012	6.012
Chan Chen Wai	9	6.75	6.762	6.762

Fig. 7. MiniOSN 2.1's Log Data page

B. User Acceptance of MiniOSN 2.1 with EABT Algorithm

The aim of this user-acceptance survey is to evaluate user acceptance of the rating idea used within EABT algorithm. A total of 28 participants who are actively using OSN were interviewed. Most of the candidates have IT knowledge, background and fall within the age range of 20 to 24 years old.

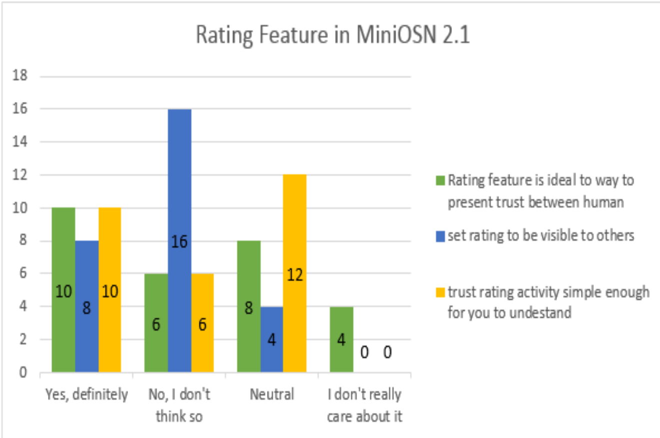


Fig. 8. Rating Features in MiniOSN 2.1

Based on the data interpreted in Figure 8, most participants stated that the rating feature in MiniOSN is an ideal way to present trust between human. On the contrary, most of the participants are unwilling to set rates to be visible to others, this might due to the human physiological factor to avoid any hard feeling or unnecessary misunderstandings to people or friend in social media. The enhanced algorithm also helps participants to learn more relate to privacy and confidential of oneself when being personal information is being exposed in social media sites. Participants hope that the rating is confidential and it only use to guess the users' behavior characteristic. Through rating, user can choose to preserve confidentiality more effectively. On the other hand, few of the participants refuse to use it, as the rating is time consuming for those who tend to have a lot of "friend" in social networking sites. Similarly, some users are not specifically familiar with the calculation of the Trust Factor (seed values, Tf). Nevertheless, the whole concept is rather basic and simple to understand for the user. It is common to be compared to other online social networks, because trust values are part of the functionality in which online social network should take into account.

V. Enhanced Trust Network based Context Recommender Mathematical Model

In order to obtain a better understanding of how Trust Network Based Context Recommender Mathematical Model [17] can be integrated in OSN as trust computational mechanism, the understanding on how recommender system works as a tool for web applications is essential.

Figure 9 describes the flow of prediction calculation of trust network-based context aware recommender system. Trust parameters and selection & weighting of relevant context are used to build a neighborhood for the target user. The task in the trust network-based context aware recommender system is to predict the ratings of a particular user which we refer to as the target user.

Rating Database: We need a database of votes or ratings from a population of users' friends. Each rating in the database corresponds to the rating from a single user on specific friend.

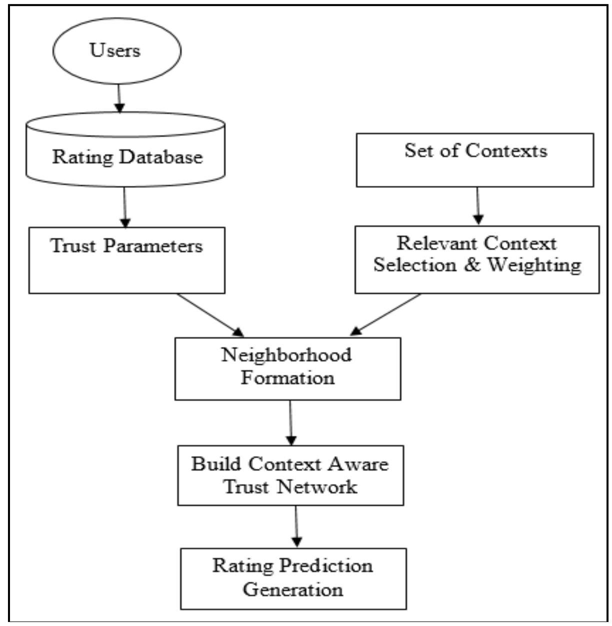


Fig. 9. Prediction calculation for Context Aware Recommender System

Trust parameters: Trust parameters are used to build a neighborhood for the target user, it is used as the input for trust calculation to generate trust values between rating values of a pair of users given towards a specific friend.

Set of contexts: Referred as trust attributes in this research, which are reputable, reliability, confidence, competency, credibility, honesty, belief and faith.

Relevant contexts selection & weighting: Eight trust attributes are selected as our relevant contexts and weights of each of eight trust attributes are used as parameters to build neighborhood for the target user as well.

Neighborhood formation: Neighborhood formed when the trust value of a friend is being calculated or updated. Trust values represent the trust that the target user holds for a specific user. The overall trust value will be updated each time the target user provides a rating to a new friend or recommended friend.

Build Context Aware Trust Network: Trust network is built when trustworthiness of each of every friend of target user is being generated, then its target users.

Rating Predication Generation: Rating prediction is being generated for a target user using the target user's neighborhood and applying the context weighted trust formula.

In [17], trust is defined as the ability of a user to provide accurate recommendations. Trust values are calculated between in pair of users and trust values are asymmetric. Dutta et.al [17] has proposed the prediction calculation for a trust network based context aware recommender system which was modified from [18] formula to generate rating prediction where user p is the sole contributor instead of all users in the neighborhood contribute to the rating prediction. $\bar{r}_c$ or $\bar{r}_p$ refers as the average friends' rating value of user c or user p.

$$P_{c,i} = \bar{r}_c + \frac{\sum_{p\in M} sim(c,p)(r_{p,i} - \bar{r}_p)}{\sum_{p\in M} |sim(c,p)|} \Longrightarrow P_{c,i} = (\bar{r}_c - \bar{r}_p) + r_{p,i} \quad (2)$$

(Resnik's formula)

where

$P_{c,i}$ = Predicted rating for target user c on a specific item i,

$\bar{r}_c$ = Average rating of user c,

$\bar{r}_p$ = Average rating of user p,

$r_{p,i}$ = Rating of user gave to friend, i.

$T_{c(p,i)}$ represent the friend-level trust value,where p is the user who provided the rating prediction on friend I, and c is the target user. Target user, c refers to the user profile receiving the friend recommendario, and user *p* refers to the profile that has been selected as a recommendation partner for user c. In multi-facet environment which uses the range of 1 to 10 rating scale, Z_{max} would be 10 and Z_{min} would be 1. The result for friend-level of trust range from [1,0], where a larger value means the prediction was more accurate.

$$T_{c(p,i)} = 1 - \frac{|P_{c,i} - r_{c,i}|}{Z_{MAX} - Z_{min}} \quad (3)$$

where

$T_{c(p,i)}$ = Trust of target user c for p for a specific friend i,

$r_{c,i}$ = Target user's actual rating on friend i,

Z_{max} = Top of rating scale,

Z_{min} = Bottom of the rating scale.

The trust value which a target user holds for all other users will vary time; this represents the personalized trust. Because the dynamic of trust needs to be infused in the recommender system to enhance the accuracy, incorporation of relevant context parameters in the trust network will be resolved this issue. In order to take context weightings (important factors) into consideration, for equation in (3) is modified again to $WT_{c,i}$ as shown in (4) below.

$$\mathrm{WT}_{(c,i)} = T_{(c,i)} \left[X + Y . \frac{\sum_{q=1}^{m} w_q}{\sum_{q=1}^{r} w_q} \right] \quad (4)$$

where

$WT_{c,i}$ = context weighted trust value.

X,Y = Two real number such that X+Y = 1,

m = number of matching contexts,

r= number of relevant contexts selected, $r \geq m$.

Equation in (4) takes into consideration, the effect of relevant contexts on the trust value and derive the context weighted trust value. In this research, the weightage of trust attributes will be inhabit into the equation in (4). *r* is the number of relevant contexts selected, *r* is equal to 8 because we are using all eight weighted trust attributes to calculate trustworthiness of a user. In this approach, both user rating and user's friend rating will be considered as the parameter to compute the trust value. *m* refers to the matching contexts between target user *c* and user *p* given the rating value towards eight trust attributes in the prototype. *X* and *Y* are the real number such that *X* + *Y* is equal to one, different combination value of *X* and *Y* will produce varies weighted trust score. In our case, the value of *X* and *Y* would be 0.5, based on the experiment carried out by the authors in [17], MAE of each of different set of *X* and *Y* were captured to measure the accuracy of prediction. MAE known as Mean Absolute Error to measure the average absolute deviation between predicted ratings and users true ratings. If MAE is small, it indicates high prediction accuracy. A combination of value of 0.5 for both *X* and *Y* generate the smallest score of MAE among all different combinations.

A. *Proposed Trust Prototype with Enhanced Multi-Facet Trust with Context Recommender Mathematical Model [EMF –CRMM]*

With influences from multi-faceted trust model and ranked weights trust attributes in the author first findings, MiniOSN2.2 is proposed with trust computation mechanism different from miniOSN 2.1. Rating feature will be demonstrated in MiniOSN 2.2 as well, rating activities are part of the process of trust computation, in MiniOSN 2.2 trust rating of another user takes into consideration as one of the important factors to calculate trust. User needs to enter the rating value of each trust attributes. Rating value range from 1 to 10, when trust value is being calculated, the system will look up for a matching rating value of these trust attributes between the user and recommender partner.

B. *User Acceptance of MiniOSN 2.2 with EMF –CRMM*

The aim of this user-acceptance task is to evaluate user acceptance in term of the applicability of trust network based context recommender mechanism is applicable in OSN. All participants who are active in OSN and with some knowledge of practice of online social network are chosen.

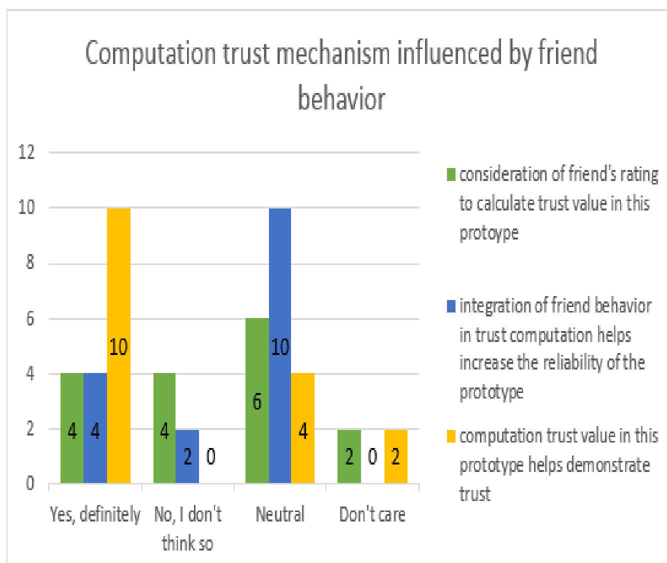


Fig. 10. Computation trust mechanism influenced by friend's behavior

In MiniOSN 2.2, trust rating value of a friend is taken into account for trust value calculation (see Figure 10). In this research, implementation of trust computation mechanism with trust network-based context recommender model in MiniOSN 2.2 aims to help users to express trust, 62.5% of participants' respondents the prototype successfully demonstrated the trust. Generally, participants described the ideal experience from this prototype are showing a good response. Despite the issues in the design of the user interface and the ambiguity of navigation in the prototype, enable trust rating from a recommender partner to a friend in this prototype which is said to be able to increase the trust and privacy awareness among social users in this survey finding. There are mixed opinions provided by participants when the question asked participants to compare the social network of incorporating rating and trust computational mechanism with other online social networks. Some of the participants responded that this is the first time experience obtained from a participant have this rating feature with computational trust system and is not familiar for them to be seen on other social network sites. While some participants responded it was good to bounce ideas off other social networks, which acts like feedback from customer on shopping sites like Lazada.

C. Comparison between MiniOSN 2.1 & MiniOSN 2.0

From the evaluation results, the authors found that most people felt that the trust computation mechanism of recommender model would be more transparent compare to action-based trust model. The result showed that most people are keen to express subjective views of trust depending on the context among connected friends in OSN. Also the result showed most people felt that both mechanisms help them to gain a better control over the resources in an online profile. However, some enhancement and modification should be done, especially on the structure and design of both prototypes.

Overall, EABT algorithm has better reviews in term of user-friendly in system, this is due to the workload of rating friends is much easier and convenient. In MiniOSN 2.2, users need to go through additional process or step while rating friends, there is users need to send a request to a recommender friend providing he/she own rating based upon confirmation of friend request. This makes the rating process in OSN take a longer time, which means lack of user friendliness thereby reducing the effectiveness of the computation of the system if there is any delay in responding for providing rating value from a recommender friend. Another downfall in recommender model is the need for human contact or support in providing feedback rating continuously from time to time for the user would make the system look clumsy. An efficient system should prevent or reduce occurrence of human intervention. In order to provide a reliable trust rating and a computational mechanism within OSN, user needs to understand each setting correctly. There should still be standard to follow by the user to avoid any argument when rating a friend. Based on the comparison and evaluation of both models, the authors demonstrate that EABT algorithm takes a preemptive than the recommender model in term of efficiency. In conclusion, from all the results of these surveys, trust needs to be taken into account in OSN. As most of the active OSN users believe that OSN should provide a better control on user own resources or profiles that are personalize-able by integrating element of trust. Implementation the concept of trust and computational mechanism in OSN is expected by most of the users. Trustworthiness of OSN needs to be guaranteed in order to protect user privacy and to win the user's heart.

VI. Conclusion& Future Works

The current OSN is suffering the lack of trust or confidence in the opinion expressed in the web-based social network where the degree of trust among the users is absent. Current trust mechanisms used in OSNs are limited to simple privacy settings where users can control who can view their profile and interact with them or can include them in some community. Trust propagation does not manifest itself as a physical phenomenon in nature, but only exists at the mental and cognitive level. It is therefore difficult to assess whether computational models for trust propagation are adequate and reflect the way people reason about trust. Throughout the study, the author discussed that how the multi-faceted model of trust based on eight trusts attributes that implemented into OSN, where the trust concerns are taken based on the eight important traits: honesty, reputation, competency, credibility, confidence, reliability, belief and faith [1, 12]. The author next we set the weightage and by using statistical means, ranking of each attribute is determined [23].

Secondly, the input of [23] is then applied together into the proposed EABT algorithm and EMF–CRMM model. The simulation of prototype of these two models has been developed to use it as the mean to collect the data joint with the web-based questionnaire for this evaluation. Rating feature is demonstrated in both proposed computational trust models in the social network for most of our evaluation participants felt that it helps users to obtain a better control over their online resources in a profile which enable them to express their trust depend of the context and personally in OSN. Evaluation regarding the functionalities and acceptance of MiniOSN 2.1 and MiniOSN 2.2 are examined based on user opinions and overall satisfaction towards the developed prototype seems through second survey and third survey which targeting only active OSN users. Overall the proposed conceptual framework received positive reviews from participants, however opinion seems still to waver if it is integrated into current OSN. People tend not to judge people by those values generated by a machine rather they judge from the abstract aspect, such as sensitivity or feeling they felt for others. The authors suspect that such a proposed model would work well in an e-market environment, where users do not have previous relationships offline and are building trust for each other from scratch.

However, there is also no standard tool or method to measure the accuracy of trust value being generated by computational trust mechanism that integrated in OSN. Despite all the privacy and security issues in OSN, trust must be enforced to increase the trustworthiness of a social network site in order draws back the heart of the user to use it. Where there is the high levels of trust, people are more willing to provide support and take risk in information exchanges. In future, more research focusing into computational trust for inputting feedback ratings in OSN must be done. As for future work, trust calculation algorithm or mathematical model that is resistant to attacks such as Sybil attack, and is applicable to the Quinn's multi-faceted model [12] of trust in this research could be implemented and evaluated.

Such an algorithm should highlight because it could enhance the trust management service in OSN by providing accurate recommendations. Another focus would be to study the effect of distrust in the multi-facet model.

References

[1] Liu Ban Chieng , Manmeet Mahinderjit Singh , Zarul Fitri Zaaba, Rohail Hassan, *Multi- Facet Trust Model For Online Social Network Environment*, International Journal of Network Security & Its Applications (IJNSA) Vol.7, No.1, January 2015

[2] Gross.R, Acquisti.A, *"Information Revelation and Privacy in Online Social Networks(The Facebook case)"*, WPES '05 Proceedings of the 2005 ACM workshop on Privacy in the electronic society, pp. 71 – 80, doi:10.1145/1102199.1102214

[3] Johnson.H et.al, *"On the Concept of Trust in Online Social Networks"*, Trustworthy Internet, Springer Milan PP. 143-157, [online] http://link.springer.com/chapter/10.1007/978-88- 470-1818-1_11#.

[4] Ruohomaa.S et.al (2005). *Trust Management Survey*. *Lecture Notes in Computer Science.* Springer Berlin Heidelberg.Vol. 3477, pp 77-92 [online] http://link.springer.com/chapter/10.1007%2F11429760_6#

[5] Sabater.J, Sierra.C; "*Review on computational trust and reputation models*"; IIIA-CSIC, Campus UAB, Bellaterra, Barceloana, Spain; September 18, 2003.

[6] Hamdi.S,Bouzeghoub.A, Lopes Gancarski.A, Ben Yahia.S, "*Trust Inference Computation for Online Social Networks*", TRUSTCOM, 2013, 2013 12th IEEE International Conference on Trust, Security and Privacy in Computing and Communications (TrustCom), 2013

[7] Boyd, D.M., Ellison, N.B.: *Social network sites: definition, history and scholarship*. J. Comput. Mediat. Commun. 13(1), 210–230 (2007).

[8] Beye, M., Jeckmans, A. J., Erkin, Z., Hartel, P., Lagendijk, R. L., & Tang, Q. (2012). *Privacy in Online Social Networks.* In Computational Social Networks (pp. 87-113). Springer London.

[9] Gambier, M. N Doja, and Moinuddin, "*Action-based trust computation algorithm for Online Social Network*", Proc. of 2014 Fourth International Conference on Advanced Computing & Communication Technologies, Rohtak. N.p., 8-9 Feb. 2014.

[10] Lu.G et.al (2009). "*A Review on Computational Trust Models for Multi-Agent Systems".* The Open International Science Journal, 2009, 2, Pages 18-25.

[11] Savec.T, Samek.J (2013). "*Trust evaluation on Facebook using multiple contexts*". *DECEUR Workshop Proceedings.* 2013, vol. 2013, no. 997, pp. 23-32. ISSN 1613-0073. Available from: http://www.ceur-ws.org/Vol-997/trum2013_proceedings.pdf

[12] Quinn.K et.al. (2009). "*An analysis of accuracy experiments carried out over of a multi- faceted model of trust"*. International Journal of Information Security. Springer-Verlag. Vol. 8, Issues 2, pp 103-119 [online] http://link.springer.com/article/10.1007%2Fs10207-008-0069-7

[13] Kleinberg, J.: "*Authoritative sources in aHyperlinked Environment*." In: Proceedings of the 9th ACM-SIAM Symposium on Discrete Algorithms (1998).

[14] Salama, M., et al., "*Computational Social Networks: Security and Privacy, in Computational Social Networks"*. 2012, Springer. p. 3-21.

[15] Karuppanan, K. (2012). *"Security, Privacy, and Trust in Social Networks. In Computational Social Networks (pp. 23-53)".* Springer London.

[16] McDowell, M., Morda, D.: *"Socializing securely: using social networking services".* United States Computer Emergency Readiness Team (US-CERT), Washington, DC (2011)

[17] PallaDutta et.al; *"A Novel Approach to Trust Based Recommender Systems Leveraged by Context Attributes"*. International Journal of Engineering and Technology(IJET). Vol 6 No 3 Jun-Jul 2014, pp 1480-1486.

[18] Kristen Mori. *"Trust Networks in Recommender Systems".* 2008. Masters Project, San Jose State University.

[19] Gerstman B. (Sep 2004). Online lecturer note of San Jose State University: Chapter 14 Correlation. Retrieved http://www.sjsu.edu/faculty/gerstman/StatPrimer/correlation.pdf

[20] Steven B. Achelis. Technical Analysis from A to Z. Retrieved From: http://www.metastock.com/customer/resources/taaz/?c=3&p=44

[21] Raj Gunesh. Online lecturer note: Statistic Correlation Analysis. Retrieve From: http://pages.intnet.mu/cueboy/education/notes/statistics/pearsoncorrel.pdf

[22] Mahinderjit Singh.M, Liu.B.C, Hassan.R , Zaaba.Z.F, "*Friends Personalization of Trustworthiness forPrivacy Perseverance in Social Networking"*, Proceedings of the World Congress on Engineering and Computer Science 2015 Vol I WCECS 2015, October 21-23, 2015, San Francisco, USA.

[23] Chin Teo Yi, Manmeet Mahinderjit Singh , "*Multi-Facet Trust Factors Ranking With Correlation Analysis Technique: A Case Study on Online Social Network (OSN)* ", 26th International-Business-Information-Management-Association, Madrid, Spain Nov11-12, 2015 VOLS I - VI, 2015 pp: 1812-1822

[24] Stephen, M. (1994). Formalising trust as a computational concept. Ph. D dissertation. University of Stirling, scotland.

Mobile Software Testing: Thoughts, Strategies, Challenges, and Experimental Study

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***Abstract*—Mobile devices have become more pervasive in our daily lives, and are gradually replacing regular computers to perform traditional processes like Internet browsing, editing photos, playing videos and sound track, and reading different files. The importance of mobile devices in our life necessitates more concerns of the reliability and compatibility of mobile applications, and thus, testing these applications arises as an important phase in mobile devices adaption process. This paper addressed various research directions on mobile applications testing by investigating essential concepts, scope, features and requirements for testing mobile application. We highlight the similarities and the differences between mobile APP testing and mobile web testing. Furthermore, we discuss and compare different mobile testing approaches and environments, and provide the challenges as emergent needs in test environments. As a case study, we compared the testing experience of hybrid application in an emulator and a real world device. The purpose of the experiment is to verify to which extent a virtual device can emulate a complete client experience. Set of experiments are conducted where five android mobile browsers are tested. Each browser will be on a real device as well as an emulated device with the same features (CPU used, memory size, etc). The application will be tested on the following metrics: Performance and function/behavior testing.**

Keywords—Software Mobile Testing; Software Testing; Mobile Performance Testing; Hybrid Mobile Application

I. Introduction

The last few years have been revolutionary for mobile devices. The mobile device was transformed from simple reutilized operation device to a more complicated and sophisticated one. Mobile applications become extraordinary when adopted by individuals and organizations to organize and manage almost every single life activity [1, 2, and 3]. Mobile devices are a necessity in our lives due to attributes like: ubiquity which means availability anywhere at any time, convenience, instant connectivity, personalization, and location-based services [4]. Mobile applications become so popular and available in different types and for different purposes. With the fact that more than one billion smart phones were sold and 6.8 billion mobile subscriptions worldwide in 2013, more than 300,000 applications have been developed [5], and a prediction of 76.9 billion global downloads in 2014 [6], the importance of testing these applications is surfaced for both privacy and security purposes [1].

The mobile application landscape is continuously growing and highly dynamic. The widespread availability of mobile devices combined with the declining prices and increased functionalities make them more powerful than a PC. The handset culture and improvement of bandwidth, and other factors together encourage the new operating system versions releasing and various types of mobile applications developing [4]. Testing mobile applications is an expensive, time consuming and complex process [2, 3, and 7], but it is still required and needed to guarantee consumer's satisfaction every time they use the mobile applications. It's vital to make sure to test the application by specialist and experienced testers not just to find errors but also to critique the quality of mobile applications before release it in the market to avoid exploring problems by consumers who could simply never use the application again, and you may never hear a word from them [2].

Testing mobile applications is essential to ensure the usability, mobility, and security of the applications. One of the main challenges of testing a mobile is the high cost and availability of devices. More and more companies rely on emulators in the early stages of development.

In this paper, we compared the testing experience of hybrid application in an emulator and a real world device. The purpose of the experiment is to verify the extent to which a virtual device can emulate a complete client experience. Mobile device browser engine is an example of a hybrid application that combines the features of web applications and native applications. Web browsers have access to hardware of mobile devices to provide native features such as GPS localization. They also benefit from a server side technology used in mobile web application.

The rest of this paper is organized as follows. Section 2 provides an overview of Mobile application testing scope and requirements. Section 3 gives a brief description about mobile application testing strategies. Challenges of testing mobile application are presented in section 4. Experiment Setup is described in section 5. Section 6 presents the analysis and discussion. We conclude the paper in section 7.

II. Preliminary Inspection

In this paper, we addressed the following five research questions:

1) Are mobile applications different than familiar software's?

2) What are the types and characteristics of mobile applications?

3) What are the scopes, types, and strategies of mobile application testing?

4) To which extent virtual device can emulate a complete client experience? In terms of performance and functioning.

5) What are the requirements, and distinct features in mobile application testing?

6) What are the challenges and solutions of mobile testing?

A. What is a mobile application?

Mobile applications are application software designed and implemented to run on smart phones, tablet computers, and other mobile devices with operable graphical user interface (GUI) to perform certain tasks. They are rapidly developing segment of the global mobile market and can be downloaded through USB / WIFI or can be downloaded by a web server over internet [1, 7, and 8] It is necessary to differentiate mobile applications from the traditional ones. While the mobile applications are designed and implemented to support mobility devices, the traditional ones are more likely implemented to run on desktop computers. The former is also aware of the environment in which it runs and adapts according to its computing, user, physical, or time context which is known as context awareness computing. Thus, mobile applications require specialized and different testing technologies [1, 3, 8].

There are mainly three types of mobile applications: mobile apps, mobile web applications and hybrid mobile applications [1, 3]. Mobile apps, known also as App4Mobile [1], are native mobile applications deployed and executed on mobile devices with limited resources and driven by user inputs. These applications usually depend on native mobile API "Application Programming Interface" and dongles on mobile devices such as camera [1]. This kind of application can be seen as offline application which could be run and used without need of Internet connection driven by user and make use of contextual information to generate context-based output [8, and 9]. This type of applications is built for a specific platform with the platform software development kit (SDK) tools and languages, typically provided by the platform vendor [10].

Mobile web applications are server-side apps built with any server-side technology. Mobile web client software are run and used over web browser. It's an online application form that could be run using Internet connection such as YouTube application [3]. Some applications could be hybrid form of applications. These applications run on the device, and are written with web technologies (HTML5, CSS and JavaScript) it is run inside a native container, and leverage the device's browser engine (but not the browser) to the HTML and process the JavaScript locally [1, 3, 8].

Regardless of business objectives or usage purposes, mobile application has to have some qualities and distinctive characteristics to be successful, like: connectivity, convenience (quality design), supported devices, new programming language, and context awareness [1, 8]. Other researchers mention more characteristics like: security, personalization, reachability, and localization.

Since mobile devices are almost always logged in to the mobile network, it makes mobile applications always connected. The mobile network may vary in speed, reliability and security. Therefore functional testing has to be performed in different networks and connectivity scenarios. Graphical user interface must be tested in different devices to test the ease of use or convenience of mobile application. Mobile application has to be easy to install, easy to access, and easy to use[1, 8, 9]. Mobile Applications Usability Testing Challenges and Methodologies are discussed in detail in [18, 19].

The availability of various mobile devices supported with a different software features ,hardware components, and operating systems makes testing process more and more difficult. To make sure that the application is compatible and functional for all devices we demanded to perform testing on varied combination of devices with right combination of OS. This covers the characteristic of supported devices or platform appropriate characteristic, new programming language designed to support mobility, managing resource consumption, and handling GUIs. Therefore, conventional testing techniques need to be revised to be applied to new mobile programming languages. Context Awareness means that mobile applications use data provided by context providers, which are sensing like light and connectivity devices. Those devices may provide a huge amount of inputs that vary depending on the environment and/or user actions. This requiring context-specific test selection techniques and coverage criteria have to be introduced [1, 8, and 9]. They should be unique and not be a mirror of what your competitor provides. This will add value to your application. The level of enjoyability and entertainment are important features to differentiate any mobile application. Mobile applications tend to be more focused and more determinant purposes, deals with short duration activities. There are several factors to be kept in mind while designing mobile applications such as using mobile applications in different places either quiet, appropriate or crowded and noisy places. Therefore, designing an application with only speech input is not a great idea, and at the same time, the mobile device itself should not be a disturbing source to others [20]. Different types of mobile applications with various characteristics mean definitely different approaches and techniques of testing and increase challenges of testing; the following section will discuss the scope and types of testing in depth.

B. Mobile Applications Testing Scopes And Types

The term Mobile application testing refers to testing the activities for mobile applications on mobile devices using well defined software test methods and tools. Testing is needed to ensure quality of service (QoS), mobility, usability, interoperability, mobile connectivity, security, and privacy, [3, 12] are working as desired. Mobile applications are getting more and more complex, which make testing their stability and robustness [13] is necessary. Mobile applications testing process is complicated for several reasons: high dynamicity in the mobile phone manufacturing world, frequently updating software, and lack of unified supporting test operations where each application has its own unique business and data flow [3, and 12]. Testing mobile applications can be done using different approaches for different objectives, that is, hardware compatibility, software reliability, application functionality etc.. Some testing mobile application purposes are summarized as follows:

- Mobile function and behavior testing: this refers to checking the validity of mobile functions and behavior under all possible situations [3].
- Mobile system QoS testing: check the mobile application scalability –ability to handle a growing amount of work in a capable manner -, reliability –consistency- , availability –instant connectivity and operation-, and performance [1, 3, and 8].
- Mobile interoperability testing (compatibility): checking the mobile application crossing different platforms to make sure that the application is compatible with other applications and promotes cross-use functionality [1, 2, and 3].
- Mobile usability and internationalization testing: internalization refers to reviewing the design and development of software or Web applications to make sure if it can be easily adapted to various linguistic and cultural environments without additional programming. Internationalization reduces time and cost of getting a product to international markets and facilitates localization of the product in a specific market. Usability includes text visibility on the selected language, navigation between screens, and functionality of online/offline [3, 14]
- Mobile system security testing: concerning the privacy of personal and business stored information on mobile devices include inscription/decryption techniques used for sensitive data. Attacking security may come from means of communication like SMS, MMS, WiFi, and Bluetooth, or may exploit software vulnerabilities from both the web browser and operating system [1, 3, 8].

Other dimensions of testing include: mobile multi-tenancy testing "validates Software as a Service -SaaS- features and QoS requirement, mobile connectivity testing "validates mobile application in different wireless network connectivity and context environment[9]. System mobility testing "validates location-based mobile system functions, data, user accesses, and services" [14].

C. Mobile Applications Testing Requirement And Features

We are moving from a PC society to a mobile society, which has become a dominant phenomena, where more processes are done by mobile devices, and more personal and business information is stored and accessed from these devices. Unlike conventional application testing, mobile application has set of distinct requirement and features, such as [3]:

1) Testing anytime and anywhere: mobile applications are accessible at anytime and anywhere; therefore mobile application function should be correct anytime and anywhere.

2) Testing crossing mobile platforms and browsers on variety of mobile devices: mobile devices have different operating systems; display dimensions, hardware appliances, and battery operation time. Therefore testing mobile applications must be conducted on selected device with a diverse mobile platform.

3) Testing for good and rich mobile experiences: mobile applications are designed and developed to support high experienced users by providing multiple input channels, rich media features, native application interfaces, and hardware equipment.

4) Testing using large-scale mobile simulation and virtualization: this is required to evaluate mobile application performance and scalability so that hardware costs can be reduced

5) Testing with divers network connectivity: mobile applications must be validated under different network connectivity and related contexts, because mobile devices support diverse wireless network connectivity (such as 3G, Wi-Fi, and Wi- Max).

III. Mobile Applications Testing Strategies

Mobile application testing represents many techniques and tools to meet quality requirement and can be classified in different ways. One of these classifications is based on the underlying client and server infrastructure. There are mainly four approaches to this classification:

1) ***Device Emulator*** [2, 3, 9, 10,and 14]: 30%-40% of tests are performed using this approach. In this approach, quality assurance team validates mobile applications using emulator on mobile devices with various options like ability to bypass the network, and use of an effective scripting language. A tester can easily switch to different device types by simply loading the appropriate device profile [13]. This is a cost-effective approach because no real devices are needed during testing. Emulators are mostly available free and different types of testing like user interface, stress, and performance testing can be performed using emulators. The disadvantage of emulators is that they lack the peculiarities; in case of running the same tests on the same mobile device may not reflect the actual results [2, and 13]. Moreover, the availability of limited number of emulators while there are large numbers of mobile phones and those emulators may have bugs that cause suspicious defects reported [2]. Muccini and Kirubakaran [1, 8] state that simulation-based mobile testing is similar to emulator in that no real mobile devices are required, but differ in the ability of simulating different mobile behaviors on selected mobile devices. However, still both emulator and simulator have shortage and weakness in testing devices-based native mobile function features.

*2) **Mobile Cloud Computing Solutions**:* in this approach mobile device can be accessed through web interface and the applications can be deployed, tested and managed remotely. This approach is cost effective since it uses pay-as-you-use service model, reducing complexity of the implementation, and keeping tasks and data on the Internet rather than on individual device providing on-demand access. There are several benefits of using cloud solutions, such as 1) reducing the cost through using rent per hour/ swap devices technique, 2) there is no need to cell plan for testing income calls and text, 3) investigating failures by recording video of automated text execution, 3) recording device log to help in trouble shooting, 4) availability of large number of devices for testing, and 5) test can be run on several devices in parallel[1, 2, 3, 8, and 10].

*3) **Real Time Devices with Real Networks:*** this approach is a device-based mobile testing, where real mobile devices are purchased and used by enterprise-based test laboratory to validate application functionality, dynamic behavior, and QoS parameters, this approach is cost consuming as actual devices are needed. The last approach uses automation Tools to avoid manual work, and quality assurance team automates mobile application tasks to reduce time and cost., Examples of available automation tools for mobile applications are: Android, Android instrumentation, QTP(Paid), iOS, and more [2, 3, 15, and 16].

IV. Challenges of Testing Mobile Applications

Mobile application testing is an activity aimed at evaluating and improving the quality of the application by identifying defects and problems. The testing process and its results must consistent and unbiased, this create a diverse set of challenges and barriers at different testing levels. At this point we might need to make a tradeoff between the test strategy and test effectiveness. There are no tests called perfect or complete. One may need a combination of tests to be completely satisfied. Basically barriers are covered by four dimensions described in Figure 1.

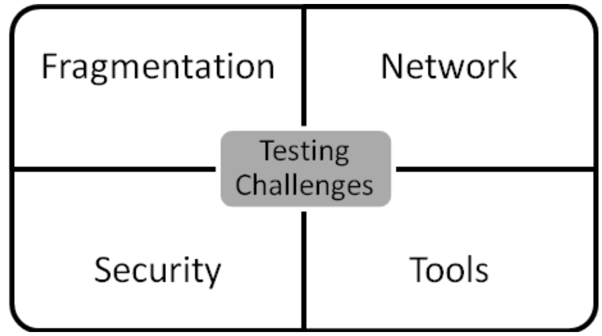

Fig. 1. Testing Challenges Dimensions

As shown on the top-left of Figure 1, the first challenge is fragmentation where there is a large number of mobile devices running on various operating systems. Different user interfaces increase level of challenge due to compatibility. Mobile devices Network performance affects user's application experience; where each mobile operator may support multiple network technologies and some use less common or local networking standards. Testing mobile application in all possible connected networks requires travelling to every network operator which can be very expensive and time consuming. We can overcome the network challenge by bypassing the lower layers of network and testing the application over Internet on network by using device emulator and thus saving time and cost of travelling. On the other hand, bypass cannot emulate the effect and timing of network. Security is another dimension of the effectiveness and validity of the application; it is essential to ensure the application is secured and does not surpass user's personal information. The last dimension of challenge is the variety of testing tools. The possibility of missing the appropriate testing tool should be taken care of as we may find a large set of tools in the literature.

According to Cap Gemini Quality Report [11], the barriers to testing mobile application have shifted from tools to methods, 56% of companies do not have the right testing process/method, 52% do not have the devices readily available, 48% do not have mobile testing experts, 38% do not have in-house testing environment, 37% do not have the right testing tools, and 33% do not have enough time to test. Nevertheless, the data shows that mobile testing rose rapidly in 2013 compared to 2012 where statistics prove that 55% of organizations implemented new methods and tools to validate functionality, performance, and security of mobile applications and devices in contrast to 33% in 2012.

Some researchers classified the testing challenges into three main categories: testing process itself, testing artifacts, and testing type. Figure 2 summarizes the challenges facing mobile application testing process.

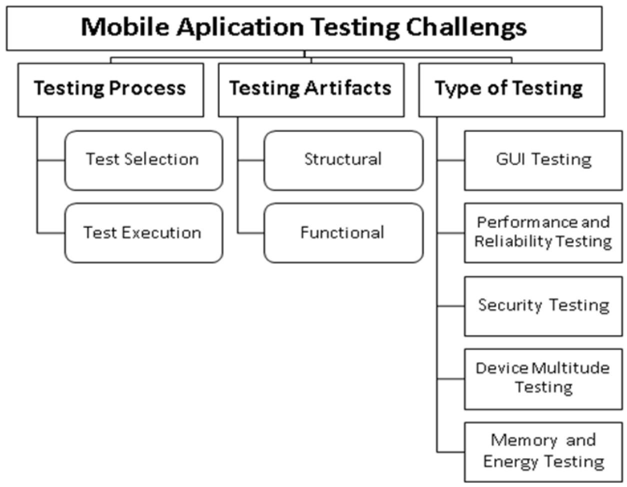

Fig. 2. Challenges of Mobile Application Testing

As we discussed earlier, mobile application can be native, web, or hybrid application and each application has distinctive purposes and structure. Testing Process Challenge based on Figure 2 is classified into two categories: test selection and test execution. 1) Availability of huge number of applications with different types and features might require new testing criteria to ensure coverage of all aspects of testing process, that is, application type, operating system platforms, full/partial capabilities etc. We can refer to this challenge as test selection challenge [10]. 2) Test execution deals with the availability of multitude of mobile devices with a huge diversity of environment. It is difficult to test the application on all devices of the same product family, even if they differ from each other in resolution, CPU, memory, and OS optimization. This leads to the challenge on how to introduce valid and reliable test cases including rich contextual inputs. Existing simulators are unable to simulate real-world phones with their sensors, GPS, connectivity. New capture-and-replay automated techniques can be realized for executing contextual inputs [13].

For testing artifact, we focused on structural and functional testing approaches. 1) Structural testing (code-based/white box testing): mobile application languages add some specific constructs for managing mobility, sensing, and energy consumption. Automated crawling testing software is considered as a powerful and cost-effective tool to set a quick test of errors and device inconsistencies. New coverage criteria can be thought of as a way to consider at best the new mobility sensing, and energy constructs. 2) Functional testing (model-based/black-box testing): functional testing requires specifying both the application and the environment it may operate in. State-based approaches can be useful to model different execution modes (e.g., low battery, meeting, and flying mode) [1, 8, 10, 15].

Mobile testing approaches are widely used in the literature. In this paper, we focus on the following strategies:

1) Graphical User Interface testing: testing whether different devices provide an adequate execution of data, and testing whether applications are correctly displayed on different devices. Automatically execute scripts that are captured during the user interaction and replayed and modified even on different devices is a good idea for testing GUI. It is important to make this task automatic to save time [3, 9, 10, 12, and 13].

2) Performance and reliability testing: mobile applications performance and reliability depends on the device resources, device operational mode, connectivity quality and variability, and other contextual information [3, 10, and 15].

3) Security testing: mobile networks have different security levels, and computer's viruses might access to personal contextual information which presents real privacy concerns. Conventional security testing techniques shall be revised to keep in consideration contextual factors that shall be simulated to check transmitted data from the mobile device.

4) Devices Multitude Testing: This kind of testing creates the biggest testing challenge. Different mobile phones provide different features, hardware components, and different O.S. This creates a challenge of cost and time consuming when using "test on many devices" approach and need to be replaced by (cost) effective automated techniques [2, 3, and 7]. We can choose one of three options to handle the device challenge: either to testing exclusively using real devices, testing exclusively using emulated devices, or using a combination of both. Using real devices will explore all the limitations in the real hardware and the firmware combination, but it can be costly and time consuming. While in other hand it is easier to manage emulated devices through the ability to load different devices updatable profiles on one platform and exchange among them in a simple and direct way which is cost effective solution, however emulators lack the limitations, and quirks, and characteristics provided by the real devices and does not cover the exact behavior for external conditions like crowding and noisy environment, also emulation depends in PC power. Another suggested solution is to release (free of cost) prototype version of the application to be tested, running it on a multitude of devices, and collect, store, and analyze run-time data and failures [1, and 8].Testing by using a combination of both emulation and real device create the opportunity to gain advantages of both approach. An emulated environment enhances the speed and device diversity at a relatively low cost. The real devices verify the applications functionality and ensure that all development objectives have been met.

Sahinoglu, *et al.* [21] highlighted mobile application testing landscape and conducted a gap analysis. They provide definitive metrics and publications about mobile application testing.

Zaein, *et al*. [22] conducted a systematic mapping study to categorize and to structure the research evidence that has been published in the area of mobile application testing techniques and challenges that they have reported. In their work, several research gaps are identified and specific testing issues for practitioners are identified.

V. THE EXPERIMENT SETUP

Testing mobile applications is essential to ensure the usability, mobility, and security of the applications. One of the main challenges of testing a mobile is the high cost and availability of devices. More and more companies rely on emulators in the early stages of development.

In this paper, we compared the testing experience of hybrid application in an emulator and a real world device. The purpose of the experiment is to verify the extent to which a virtual device can emulate a complete client experience. Mobile device browser engine is an example of a hybrid application that combines the features of web applications and native applications. Web browsers have access to hardware of mobile devices to provide native features such as GPS localization. They also benefit from a server side technology used in mobile web application.

In this experiment, five android mobile browsers will be tested. Each browser will be on a real device as well as an emulated device with the same features (CPU used, memory size, etc). The application will be tested on the following metrics: Performance and function/behavior testing.

A. *Performance Testing*

Performance is one of the most crucial aspects of mobile applications. Performance measures how fast the application starts, how fast data loads, and the overall connectivity of the application on different carriers. Many hardware related aspects, such as memory and battery consumption, are evaluated to test the usability and mobility of the application. In this experiment, the mobile devices browsers are tested on the following aspects:

- Memory consumption
- Traffic generated by the testing scenario
- CPU Usage generated by the testing scenario
- Battery Consumption generated by the testing scenario
- Initial loading speed of the application
- Duration of Testing experience

The mobile browser's performance will be tested on the following scenario:

- Open Browser
- Open google.com
- Search Android Wikipedia
- Open the page
- Close Browser

B. *Function and Behavior Testin:*

Function and behavior testing is an essential part of mobile applications testing. Functionality testing is used to validate the display of the application's content (images, texts, etc.) under different devices. It also verifies the behavior of the application under all circumstances. In this experiment, the browser will be tested based on the following functionalities:

- Auto-suggest feature for URL
- Downloading information from internet
- Uploading information on the internet
- Tab support
- Add-on support: PDF viewing, Flash player support
- Support of drowsing gestures (e.g.: double tap to zoom)
- Special function support

a) GPS support
b) Rotation
c) Camera

VI. RESULTS AND ANALYSIS

The results of the experiment are represented in Figures 3 to 6. Figure 3 is the initial loading speed of the browsers under test obtained when using Device 1 (Samsung Galaxy S3 Mini) and Device 2 (Samsung Galaxy Tab 7" inch) and their emulators. The graph indicates that there is slight difference in the initial loading time of the applications in the emulator and the real devices. The emulators were unable to give an exact estimation of the loading time of the different browser.

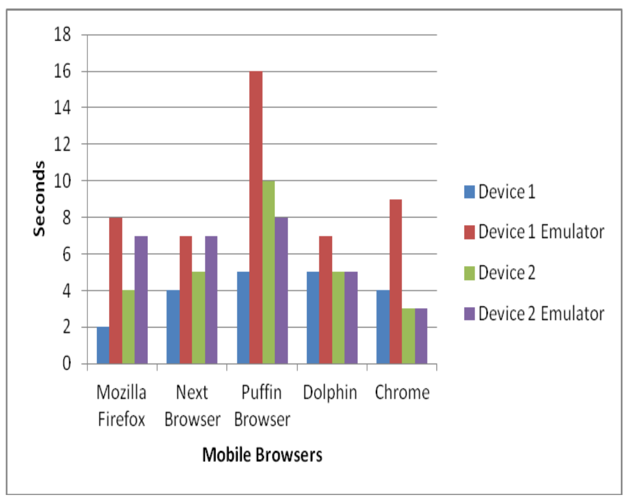

Fig. 3. A Comparison of The initial Loading Time of Mobile Browser of Real and Emulated Mobile Devices

Figure 4 illustrates the RAM usage registered for the mobile Browsers. A quick analysis of the graph confirms that the emulator were able to approximate the Ram expenditure of the mobile application four out of five times for both devices. In general, the RAM usage registered in the emulated devices was slightly higher.

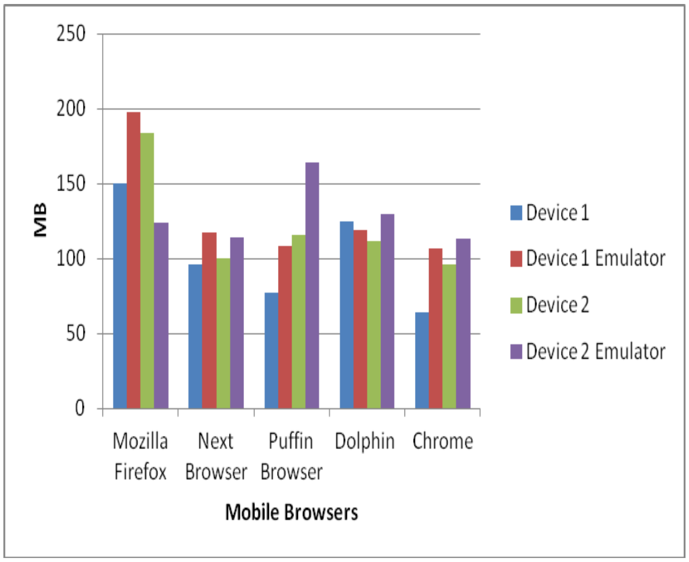

Fig. 4. A Comparison of RAM Usage for Mobile Browsers for Real and Emulated Mobile Devices

Figure 5 indicates the Application Traffic in MegaOctets. In all cases, the emulators were unable to give a correct estimation of mobile data consumption of the applications. This confirms that mobile emulators are unable to give a correct estimation of the mobile data consumption of an application.

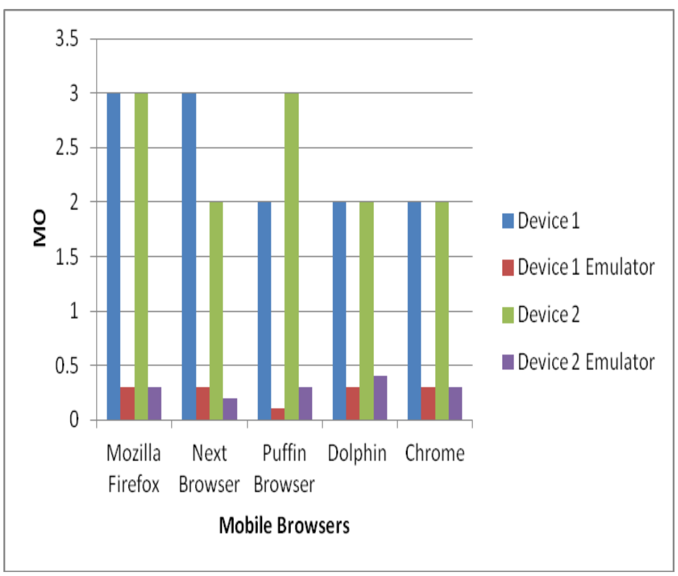

Fig. 5. A Comparison of Mobile Data Consumption for Mobile Browsers for Real and Emulated Mobile Devices

Figure 6 indicates the CPU Usage of the mobile browsers in real devices and emulated devices. The graph indicates the mobile device emulators are unable to give a correct estimation of the CPU consumption of mobile applications.

Function and behavior testing was successful. All hardware related functionalities were verified except GPS. The emulator was unable to provide the correct physical location. The emulated devices were unable to provide the battery consumption registered during the testing phase.

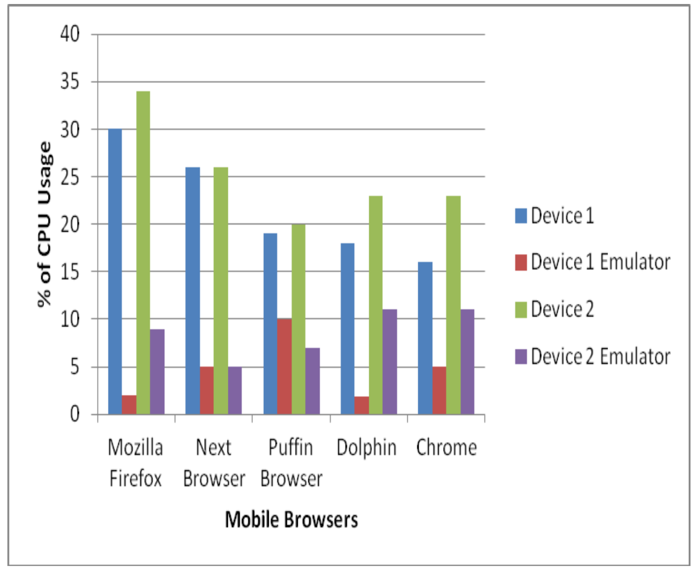

Fig. 6. A Comparison of CPU Usage for Mobile Browsers for Real and Emulated Mobile Devices

The result of our experiments confirms that mobile emulators are unable to give an indication of the performance of mobile applications. In general, mobile emulators were ideal for functional and behavioral testing for they provide a cost-effective way to test mobile application during the development phase. However, the use of real devices during testing of mobile application is essential to provide a complete user experience.

VII. Conclusion and Future Work

Automated testing approaches like outsourcing, cloud and crowed- based testing become more important as they introduce cost effective solution over traditional application testing and enabling testing through layers and clearly separate application-level failures from application framework or OS failures. It is expected that some companies might adopt As-a-Service software testing services approach, by providing special skills and laboratories to conduct thorough testing of mobile applications in an affordable manner[1, and 8].

Choosing appropriate test approach is govern by different factors, organization may choose base on economic argument, quality assurance bases, or any other restrictions. We are living in a growing world where each day brings new modifications and updates in mobile manufacturing sector in different shapes either in software development, OS, or hardware. This gives rise to more concerns about importance of efficient mobile applications testing process.. There are different approaches for testing mobile applications that may confuse organizations while making a choice. Different researchers think of different models and types for testing mobile applications [6, 7, 10, and 12]. Yet each one of these approach has pros and cons. As an attempt to find an approach that amalgamates most benefits of the other approaches, Google attempts to introduce new modular phone [17]. Google's vision for a modular phone with working user-interchangeable components will allow the users to upgrade their mobile easily and efficiently. All main components are interchangeable via modules that click in and out; this will facilitate testing process and even empower end users participation in testing process.

As a future work we intend to investigate the problem of multiplicity of testing methods and strategies by following a “hardware/software compatibility approach” which aims to manufacture mobile devices empowered with the ability to install different operating system on them “just like computers” and therefore overcome the problem of hardware/software in-compatibility, and device supporting issues.

REFERENCES

[1] Muccini, H., Francesco, A., and Esposito, P., “Software Testing of Mobile Applications: Challenges and Future Research Directions”. Proceedings of the 7th International Workshop on Automation of Software Test (AST), 2012.

[2] Huang, J., and Gong, Y., “Remote Mobile Test System: A Mobile Phone Cloud for Application Testing”, 2012 IEEE 4th International Conference on Cloud Computing Technology and Science.

[3] Gao, J., Bai, X., Tsai, W., and Uehara, T., “Mobile Application Testing” IE

[4] EE Computer, vol. 47, no. 2, pp. 46-55, Feb. 2014

[5] Information Technology for Management, 6th Ed., by Turban, Leidner, McLean, and Wetherbe, Wiley, 2008.

[6] MobiThinking Corporation, Dublin, Ireland, available: www.mobithinking.com, Access on 2016.

[7] IDC Corporate USA, available: www.idc.com, Acceess on 2016.

[8] Liu, Z., Gao, X., and Long, X., “Adaptive Random Testing of Mobile Application”, 2010 2nd International Conference on Computer Engineering and Technology, Vol. 2, 297-301

[9] Kirubakaran, B., and Karthikeyani, V., “Mobile Application Testing – Challenges and Solution Approach through Automation”. Proceedings of the 2013 International Conference on Pattern Recognition, Informatics and Mobile Engineering (PRIME) February 21-22

[10] She. S., Sivapalan, S., and Warren, I., Hermes, “A Tool for Testing Mobile Device Applications”, 2009 Australian Software Engineering Conference, 121-130

[11] Amalfitano, D., Fasolino, A., and Tramontana, P., “A GUI Crawling-based technique for Android Mobile Application Testing”, 2011 Fourth International Conference on Software Testing, Verification and Validation Workshops, 252-261

[12] Capgemini , Mobile Testing Ashift from tools to Methods, available: http://www.capgemini.com/resource-file-access/resource/pdf/wqr_2013-14_mobile_testing_pullout.pdf , Access on 2016.

[13] Liu, Z., Liu, B., and Gao, X., "SOA based Mobile Application Software Test Framework", Reliability, 8th International Conference on Maintainability and Safety, 2009, pp.765-769.

[14] Nagowah, L., Sowamber, G., and Mauritius, R., “A Novel Approach of Automation Testing on Mobile Devices” 2012 International Conference on Computer & Information Science (ICCIS), 924-930

[15] Dantas, V., Marinho, F., Costa, A., and Andrade, R., “Testing Requirements for Mobile Applications”, 2009 International Conference on Computer & Information Science (ICCIS), 555-560

[16] Kim, H., Choi, B., and Wong, E., “Performance Testing of Mobile Applications at the Unit Test Level”, 2009 Third IEEE International Conference on Secure Software Integration and Reliability Improvement, 171-180

[17] Franke, D., Kowalewski, S., Weise, C., and Parkobkosol, N., “Testing Conformance of Life Cycle Dependent Properties of Mobile Applications”, 2012 IEEE Fifth International Conference on Software Testing, Verification and Validation, 241-250

[18] Google, the ProjectAra Developer’s Conference in Santa Clara, California, available: http://www.wired.com/2014/04/google-project-ara/, Access on 2016.

[19] Anne Kaikkonen, Aki Kekäläinen, Mihael Cankar, Titti Kallio, and Anu Kankainen. 2005. Usability testing of mobile applications: a comparison between laboratory and field testing. Journal of Usability Studies, volume 1, number 1, pages 4-16.

[20] Dongsong Zhang & Boonlit Adipat, Challenges, Methodologies, and Issues in the Usability Testing of Mobile Applications, nternational Journal of Human-Computer Interaction. Volume 18, Issue 3, 2005

[21] Salmre, Characteristics of Mobile Applications, p.p 20 2004).http://ptgmedia.pearsoncmg.com/images/0321269314/samplechapter/salmre_ch02.pdf, Access on 2016.

[22] Sahinoglu M, Incki K, Aktas MS. Mobile Application Verification: A Systematic Mapping Study. InComputational Science and Its Applications--ICCSA 2015 2015 Jun 22 (pp. 147-163). Springer International Publishing.

[23] Zein S, Salleh N, Grundy J. A systematic mapping study of mobile application testing techniques. Journal of Systems and Software. 2016 Jul 31;117:334-56.

A Hybrid Data Mining Approach for Intrusion Detection on Imbalanced NSL-KDD Dataset

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***Abstract*—Intrusion detection systems aim to detect malicious viruses from computer and network traffic, which is not possible using common firewall. Most intrusion detection systems are developed based on machine learning techniques. Since datasets which used in intrusion detection are imbalanced, in the previous methods, the accuracy of detecting two attack classes, R2L and U2R, is lower than that of the normal and other attack classes. In order to overcome this issue, this study employs a hybrid approach. This hybrid approach is a combination of synthetic minority oversampling technique (SMOTE) and cluster center and nearest neighbor (CANN). Important features are selected using leave one out method (LOO). Moreover, this study employs NSL KDD dataset. Results indicate that the proposed method improves the accuracy of detecting U2R and R2L attacks in comparison to the baseline paper by 94% and 50%, respectively.**

Keywords—intrusion detection system; feature selection; imbalanced dataset; SMOTE; NSL KDD

I. Introduction

With the advance of computer science and network technology, access to internet has become an important part of people's daily life. Moreover, the number of individuals connecting to the internet is increasingly growing and this makes network security a challenging issue. Previously, authentication, data encryption, and firewall techniques were used to protect the security of computers [1].

Today intrusion detection systems (IDSs) are used to protect computer systems from the risk of threats. Generally, IDSs divide into signature-based and anomaly based detection. In signature-based detection, packets are scanned to search for a set of events previously detected as attacks. However, in anomaly-based detection, intrusion detection systems exploit behavior patterns. In fact, a profile of normal behavior is created and any deviation from this behavior is considered an anomaly. Initial intrusion detection systems widely used signature-based intrusion detection methods. However, they had a high false alarm rate. Thus recent methods are based on behavior modeling and employ data mining methods, statistical analyses, and artificial intelligence techniques to detect anomalies [2, 3].

At initial stages, most intrusion detection studies employed rule-based expert systems and statistical approaches [4]. But with advent of larger datasets the results of rule-based expert systems and statistical methods became challenging issue. Therefore, several data mining techniques were introduced to overcome this problem [5, 6].

Recently, a combination of techniques is exploited to improve detection rate and accuracy of IDSs [7, 8]. Shin, Lee, Kim, and Kim in [9] introduced a novel probabilistic approach to forecast and detect network intrusions. In this approach a Markov chain was used for probabilistic modeling of abnormal events in network systems. This is done by performing Kmean clustering, and introducing the concept of an outlier factor. Result showed that the proposed approach achieves high detection performance.

In recent years, due to the large data sets related to intrusion detection, feature selection methods (FS) are taken into consideration. FS is a process of choosing an optimal subset of features that represents the whole dataset [10]. Canedo, Marono, and Betanzos [11] proposed a new combinational method of discretization, filtering and classification which is used as an FS to improve the classification task, and they applied this method on the KDD Cup 99 dataset. Lin, Ying, Lee, and Lee [12] presented an intelligent algorithm which was applied to anomaly intrusion detection. It used simulated annealing (SA) and support vector machine (SVM) to find the best feature subsets, while SA and DT were proposed to generate decision rules to detect new attacks. Eesa, Orman, and Brifcani [10] proposed a new feature-selection approach based on the cuttlefish optimization algorithm (CFA) in order to improve performance of intrusion detection systems (IDSs). In this paper CFA used as a feature selection tool and the decision tree (DT) classifier as an evaluator on the selected features that are produced by the CFA. The performance of the proposed approach is evaluated through well-known KDD'99 data set. The results show that the feature subset extracted based on CFA gives a higher detection rate and accuracy rate with a lower false alarm rate compared to the obtained results using all features.

Several studies are done in this scope but there is no exact answer which features subsets are optimal or more representative. Also, the time taken for training the systems and for the detection task to further validate their systems is not considered in many evaluation methods. Recent systems that combine or integrate multiple techniques require much greater computational effort. As a result, this can degrade the efficiency of 'on-line' detection [1].

Lin, Ke, and Tsai in [1], tried to eliminate these limitations by combining Kmean clustering and 1-NN search algorithm. Also, execution time is reduced considerable. This approach named CANN (cluster center and nearest neighbor) is a basis

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of this paper and will introduce later in detail. But a drawback of this approach is its poor capability in detecting U2R and R2L attacks.

In some studies, overall detection accuracy was measured and showed high DR rate, but the accuracy of each attack class was not provided separately [13-15]. So, decide whether these methods are able to detect U2R and R2L attack classes are not possible.

The number of records in the R2L and U2R attack classes is very smaller than that of normal and other attack classes in datasets, which leads to an imbalanced problem. Each dataset with a significantly uneven data distribution between its classes can be considered an imbalanced set. Particularly, this imbalance is considered a between-class imbalance in which one class has much less instances than other classes. Classification of an imbalanced data set is a challenging issue for researchers. Most standard data mining techniques consider balanced data set and when they work with imbalanced data set, results are biased toward numerous majority class samples. So the accuracy of classification for majority class is high and is low for minority class [16].

Khor, Ting, and Amnuaisuk in [17] used under-sampling and oversampling methods to mitigate the rare class problem. First the dominant classes, i.e. Normal and DoS were under-sampled to balance the class and then used SMOTE for oversampling decreased dataset. Then the improved data set was evaluated by major learning algorithms such as Naïve Bayes Classifier, Bayesian Networks, and Decision Trees algorithms such as ID3, C4.5 and Classification and Regression Trees (CART). But these two methods were less effective in mitigating the problem because there is no significant improvement on detecting R2l and U2R.

This study aims to investigate the effect of SMOTE coupled with CANN approach which proposed by Lin et al. [1] to improve detection rate of low frequency attacks like R2L and U2R.

The rest of this paper is organized as follows. Section II introduces SMOTE and CANN methods. Section III explains the dataset, LOO feature selection, and evaluation parameters. Section IV present the experiments. Finally, section V conclude the paper.

II. Introduction of Smote and Cann Methods

A. Synthetic Minority Oversampling Technique (SMOTE)

Chawla, Bowyer, Hall, and Kegelmeyer [18] proposed a novel method called SMOTE to overcome the imbalanced data problem. SMOTE increases the number of minority instances by creating new synthetic instances instead of repeating minority samples. In this method, new synthetic instances are created based on two parameters, oversampling rate (%) and the number of K nearest neighbors. Creating new synthetic samples are related to features type (continues or nominal). If the features of the instance are continuous, the distance is calculated between the feature vector of a sample in the minority class and one of the k nearest neighbors. The computed distance is then multiplied by random number δ in range zero and one. Finally, the obtained value is added to the value of the initial vector [19]. The new feature vector is calculated as follow:

$$X_n = X_O + \delta\left(X_{oi} - X_O\right) \qquad (1)$$

Where, X_n is the new synthetic instance, X_o is the feature vector of each instance from the minority class, X_{oi} is the ith selected nearest neighbor for X_o and δ is a random number between 0 and 1.

Producing random instances for nominal features is as follows [20]: first the majority vote method is used among nominal features of the considered instance and its k nearest neighbors. If equal, one is selected randomly. In the next stage, the selected values are considered as the synthetic instance.

B. CANN (Cluster center and Nearest Neighbor)

Lin et al. [1] proposed a novel feature representation approach, namely the cluster center and nearest neighbor (CANN) approach. It works based on two distance. Since cluster centroids are a good representation of the entire data, the data is first clustered by using Kmean to extract the cluster centroids.

Next step is to measure and sum the distance (dis1) between all data of the given dataset and the cluster centers and the distance (dis2) between each data point and its nearest neighbor in the same cluster. This leads to a new distance based feature value to represent each data point of the given dataset. These two distances are added according to equation 2 and a new feature is achieved.

$$D_i = \underbrace{\sum_{j=1}^{\text{number of classes}} distance\left(D_i, C_j\right)}_{dis1} + \underbrace{\sum_{k=1} distance\left(D_i, N_k\right)}_{dis2} \qquad (2)$$

Where, D_i is the ith records in the dataset, C_j is the jth cluster centroid which is extracted by Kmean, and N_k is the nearest neighbor of D_i.Therefore, an n-dimensional records is converted to a single-dimensional one. After running the algorithm this new and one-dimensional distance based feature is used to represent each data sample for intrusion detection by a k-nearest neighbor (k-NN) classifier.

III. Implementation

This study aims to improve the ability of intrusion detection systems in detecting U2R and R2L attacks by proposing a hybrid approach which is a combination of synthetic minority oversampling technique (SMOTE) and cluster center and nearest neighbor (CANN). Moreover, this study utilizes the NSL-KDD dataset. In this study the dataset with 41 datasets is first reduced to a smaller dimensional set with 21 features using LOO method.

A. Dataset

Statistical analyses on KDD CUP 99, showed that this dataset has weaknesses that effect on systems` performance. Its major weakness is its repetitive records, which causes a bias towards frequent data. After investigating and analyzing this set, it was known that 78% of the training data and 75% of the test data are repetitive [21]. Therefore, this study uses NSL

KDD[1] . The total number of records in this dataset is 125973, where 67343 records are normal data and the rest indicate attacks. The total number of features is 41, which include numeric, nominal, and binary features. Table I presents the features, as well as their types and numbers.

TABLE I. FEATURES OF NSL KDD DATASET AND THEIR TYPES AND NUMBERS

Type	Features with their numbers
Nominal	protocol_type(1), service(2), flag(4)
Binary	land(7), logged_in(12),root_shell(14), su_attempted(15),is_host_login(21), is_guest_login(22)
Numeric	duration(1), src_bytes(5), dst_bytes(6), wrong_fragmer urgent(9), hot(10), num_failed_logins(11), num_compromised(13), num_root(16), num_file_creations(17), num_shells(18) num_access_files(19), num_outbound_cmds(20), count srv_count(24), serror_rate(25), srv_serror_rate(26), rerror_rate(27), srv_rerror_rate(28) same_srv_rate(29) diff_srv_rate(30), srv_diff_host_rate dst_host_count(32), dst_host_srv_count(33), dst_host_same_srv_rate(34), dst_host_diff_srv_rate(35),dst_host_same_src_port_rat dst_host_srv_diff_host_rate(37), dst_host_serror_rate(3 dst_host_srv_serror_rate(39), dst_host_rerror_rate(40), dst_host_srv_ rerror_rate(41)

This dataset consists of five different classes, where one shows normal behavior and the rest indicate attacks. Attacks are categorized as DoS, Probe, R2L, and U2R. The test set consists of 22544 records. Table II presents the number of occurrences for each class in the test set.

TABLE II. THE NUMBER OF OCCURRENCES FOR NORMAL AND ATTACK CLASSES

Class	Number of Samples
Normal	9711
DoS	7460
Probe	2421
R2L	2885
U2R	67
Total	22544

The training and test datasets include 21 and 37 different attacks, respectively. Some unknown attacks are placed in the test set which are not in the training set to evaluate the ability to detect these unknown attacks.

B. Feature Selection

Most fields in dataset are redundant. This number of dimensions increases the processing time and in some case degrade systems performance. This study by using leave-one-out (LOO) approach extracts important features from a total number of 41 features. The importance measure of each feature is evaluated based on the two parameters of accuracy and false positive rate. More specifically, the classification algorithm is executed with and without each feature. If the four following conditions are satisfied, the corresponding feature is considered important and remains in the dataset.

- Accuracy reduction, FP reduction
- Accuracy reduction, increase in FP
- No change in accuracy, increase in FP
- Increase in accuracy, increase in FP

The LOO algorithm is executed 41 times for the 41 features. Number of the resulted important features after executions is as follows:

1, 9, 10, 11, 12, 13, 14, 15, 17, 18, 21, 22, 25, 29, 30, 31, 32, 36, 39, 40, 41.

C. Evaluation Parameters

This study uses some assessment metrics such as accuracy, detection rate, and false alarm rate as evaluation parameters, which are computed based on the confusion matrix in table III.

TABLE III. CONFUSION MATRIX

Predicted value→ Actual value↓	Normal	Attack
Normal	TN	FP
Attack	FN	TP

TP: The number of correctly detected attacks
TN: The number of harmless application correctly recognized as harmless
FP: The number of harmless applications falsely recognized as attacks
FN: The number of attacks falsely recognized as normal.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (3)$$

$$Detection\ Rate = \frac{TP}{TP + FP} \quad (4)$$

$$False\ Alarm = \frac{FP}{FP + TN} \quad (5)$$

IV. EXPERIMENTS AND RESULTS

Figure 1 presents the proposed algorithm. First by using LOO, important features are extracted from the training dataset. Afterward, the training set is sampled 10 times, each time, the dataset is balanced using SMOTE method, and then CANN is used to classify the dataset and build a model. For evaluations, the test set is applied to the model and finally, the average of 10 executions is computed. This study uses 20% of NSL KDD dataset with stratified sampling. More specifically, each class is sampled in proportion to the percentage it covers in the original dataset. For instance, if class DoS covers 36% of NSL KDD records, the same percentage of records is still covered by the DoS class after sampling. Of course, due to the

[1] http://www.unb.ca/research/iscx/dataset/iscx-NSL-KDD dataset.html

small number of R2L and U2R records, first they are all placed in the samples and then the other three classes were sampled.

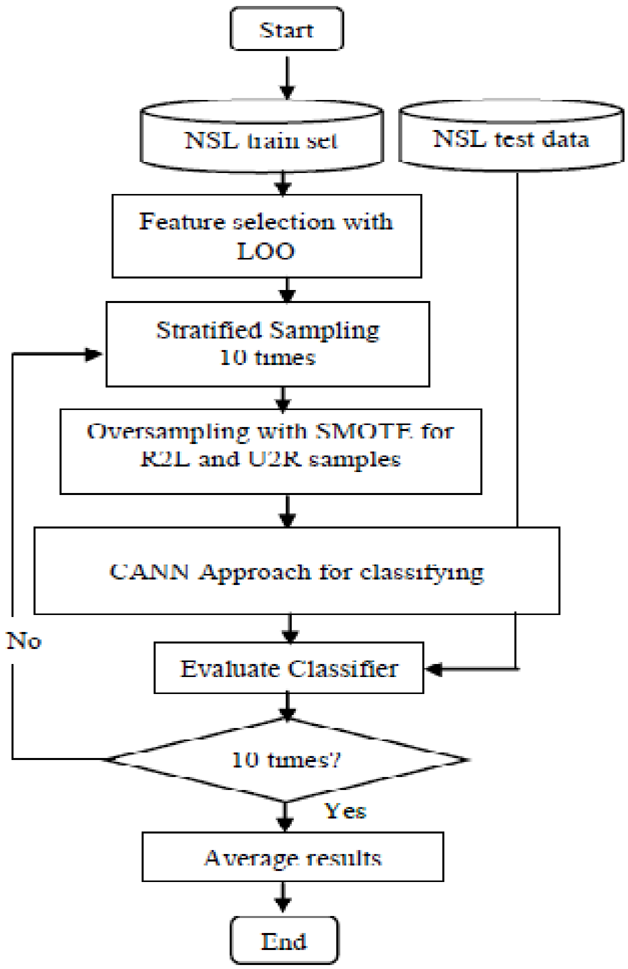

Fig. 1. Proposed algorithm

Tables IV and V present the number of percentage of each class before and after sampling.

TABLE IV. NUMBER OF RECORDS IN NSL DATASET

Class	Normal	DoS	Probe	R2L	U2R	Total
Number of occurrence	67343	45930	11656	995	49	125973
Percentage	53.5%	36.5%	9.3%	0.8%	≈0%	100%

TABLE V. THE DATASET AFTER SAMPLING

Class	Normal	DoS	Probe	R2L	U2R	Total
Number of occurrence	1269	9197	2344	995	49	25194
Percentage	50.1%	36.5%	9.3%	3.9%	0.2%	100%

Sampling was performed 10 times by changing the seed of the random number generator. Since samples are random, the accuracy of one execution of the algorithm on one set cannot be an indicator of its accuracy on the entire data. Therefore, sampling is repeated 10 times and 10-fold cross validation is used to evaluate each execution of the algorithm.

The dataset used in this study is not the same as the baseline research [1]. In order to making the obtained results to be comparable with those of the baseline study, its experiments were implemented again using the considered dataset. Related codes were written using MATLAB and all data mining tasks were performed using WEKA 6 software. In [1], the experiment was conducted on two feature sets, once with 6 features and again with 19 features, where the latter improved the ability to detect U2R and R2L attacks. This study compared with proposed method with the CANN model with 19 features.

Since training records are randomly selected, the algorithm`s accuracy changes for different records as the training set. A solution is to use probabilistic boundaries. Equation 6 shows that the probability that accuracy be in the confidence interval is 1-α. If random quantity $X = \{x_1, x_2, \ldots x_n\}$ has normal distribution with mean μ and standard deviation σ, the average sample obtained by random sampling with size n has a distribution with mean μ and standard deviation σ, which tends to a normal distribution by increasing n (equation 7). Therefore, equation 8 can be used to obtain the confidence interval for accuracy [22], where $\overline{X}$ is the mean accuracy of repeating the model by changing the seed of the random number generation and S is the standard deviation of accuracy for 10 executions.

$$\text{Probability} \quad \{C_1 \ll \mu \ll C_2\} = 1 - \alpha \qquad (6)$$

$$\sim N\left(\mu, \frac{\sigma}{\sqrt{n}}\right) \qquad (7)$$

$$\left(\overline{X} - t_{\left[1-\frac{\alpha}{2};n-1\right]} \frac{s}{\sqrt{n}}, \overline{X} + t_{\left[1-\frac{\alpha}{2};n-1\right]} \frac{s}{\sqrt{n}}\right) \qquad (8)$$

Since the seed of the random number generator is changed at each iteration and numbers are independent, we can assume that they have a normal distribution. Therefore, we can say that each iteration is performed independently and the achieved numbers have a normal distribution. Considering the 10 executions performed by changing the seed of the random number generator, tables VI and VII present the results. All parameter values are averaged over 10 executions.

Since tests and measurements are performed under the same conditions, paired systems are used to compare the results of the two approaches. Accordingly, equation 8 can be used to compare the two methods [22]. With confidence degree α of 99% and considering the number of samples as n=10, $t_{[0/995;9]}$ is 3.250. Confidence interval is obtained by replacing the mean $\overline{X}$ and standard deviation S of the sample`s differences for each parameters. The zero in the confidence interval indicates that these two methods are not significantly different.

As seen in table VI, in comparison to baseline paper [1] the proposed method has a better detection rate. However, its accuracy and false alarm rate are lower. But since the confidence interval includes zero, the different is not significant. As it was mentioned, 10 executions were performed and the table also presents the mean difference and standard deviation.

TABLE VI. THE MEAN PERFORMANCE OF THE APPROACHES

	Accuracy $\overline{X}$=0.151,S=0.712	**Detection rate** $\overline{X}$=0.450, S=0.265	**False Alarm** $\overline{X}$=-0.036, S=0.063
CANN 19 features	99.13%	99.13%	0.602%
Proposed approach	98.99%	99.56%	0.557%
99% CI	-0.580,0.882	0.178,0.722	-0.100,0.028

TABLE VII. THE COMPARISON OF THE ABILITY TO DETECT R2L AND U2R ATTACKS

Accuracy	**CANN 19 features**	**Proposed approach**
R2L	61.92 %	92.97%
U2R	28.7%	55.91%

Table VII shows that the proposed method improves limitations in detecting U2R and R2L attacks. Moreover, figure 2 compares the accuracy of detecting U2R and R2L by the two approaches.

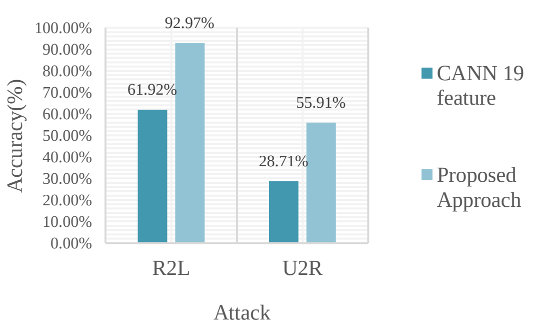

Fig. 2. The performance of the two methods in detecting U2R and R2L attacks

V. CONCLUSION

Due to the rarity of U2R and R2L records and existing of the imbalanced dataset, detection of these classes by using conventional data mining approaches in intrusion detection became a challenging problem. This study aims to improve the ability of intrusion detection systems in detecting U2R and R2L attacks by exploiting SMOTE and creating a boundary margin for low frequency attack classes, coupled with the CANN technique, which is a combination of classification and clustering. Moreover, this study utilizes the NSL-KDD dataset. In this study the dataset with 41 datasets is first reduced to a smaller dimensional set with 21 features using LOO method. Subsequently, in order to evaluate the proposed method, the dataset was sampled 10 times by changing the seed of the random number generator. Furthermore, the number of U2R and R2L class instances were increased using SMOTE. The balanced dataset was then modeled by CANN and a single-dimension dataset was extracted. At each execution of the algorithm, 10-fold cross validation was used for evaluations. Experimental results indicated that the proposed method outperforms the baseline approach regarding detection rate. However, it achieves lower accuracy and false alarm rate, which are not a significant difference. Results show that SMOTE coupled with CANN able to eliminate the limitation of the baseline research in detecting low-frequency attacks U2R and R2L and improves them by 94% and 50%, respectively.

REFERENCES

[1] W.CH. Lin, SH.W. Ke, and CH.F. Tsai, “CANN: An Intrusion Detection System Based on Combining Cluster Centers and Nearest Neighbors” Knowledge-Based Systems 2015.

[2] G.A. Marin, “Network security basics,” IEEE Security Privacy, Vol. 3, pp. 68-72, November/December 2005.

[3] M. R. Parsaei and M. Salehi “E-mail spam detection based on part of speech tagging,” In 2015 2nd International Conference on Knowledge-Based Engineering and Innovation (KBEI) (pp. 1010-1013). IEEE.

[4] C. Manikopoulos, and S. Papavassiliou, “Network intrusion and fault detection: A statistical anomaly approach,” IEEE Communications Magazine, vol. 40, pp. 76–82, 2002.

[5] P. Dokas, L. Ertoz, A. Lazarevic, J. Srivastava, and P. N. Tan, “Data mining for network intrusion detection,” Proceeding of NGDM, pp. 21–30, 2002.

[6] S. Wu, and E. Yen. “Data mining-based intrusion detectors,” Expert Systems with Applications, vol. 36, pp. 5605–5612, 2009.

[7] X. Tong, and Z. Wang, H. Yu, “A research using hybrid RBF/Elman neural networks for intrusion detection system secure model”, Computer Physics Communications 180, pp. 1795–1801, 2009.

[8] G. Wang, J. Hao, J. Ma and L. Huang, “A New Approach to Intrusion Detection Using Artificial Neural Networks and Fuzzy Clustering,” Expert Systems with Applications, Vol. 37, No. 9, pp. 6225-6232, 2010.

[9] S. Shin, S. Lee, H. Kim, and S. Kim, "Advanced probabilistic approach for network intrusion forecasting and detection. Expert Systems with Applications, vol. 40, pp. 315-322, 2013.

[10] A.S. Eesa, Z. Orman, and A.M.A. Brifcani, "A novel feature-selection approach based on the cuttlefish optimization algorithm for intrusion detection systems," Expert Systems with Applications, vol. 42, pp. 2670-2679, 2015.

[11] V. Bolon-Canedo, N. Sanchez-Marono, and A. Alonso-Betanzos, "Feature selection and classification in multiple class datasets: An application to KDD Cup 99 dataset," Expert Systems with Applications, Vol. 38, PP. 5947–5957, 2011.

[12] S.-W. Lin, K.-C. Ying, C.-Y. Lee, and Z.-J. Lee, "An intelligent algorithm with feature selection and decision rules applied to anomaly intrusion detection," Applied Soft Computing, Vol. 12, pp. 3285–3290, 2012.

[13] Z.A. Baig, S.M. Sait, and A. Shaheen, "GMDH-based networks for intelligent intrusion detection," Engineering Applications of Artificial Intelligence, vol. 26, pp. 1731-1740, 2013.

[14] E. de la Hoz, E. de la Hoz, A. Ortiz, J. Ortega, and A. Martinez-Alvarez, "Feature selection by multi-objective optimisation: application to network anomaly detection by hierarchical self-organising maps," Knowledge-Based Systems, vol. 71, pp. 322-338, 2014.

[15] G. Kim, S. Lee, and S. Kim, "A novel hybrid intrusion detection method integrating anomaly detection with misuse detection," Expert Systems with Applications, vol. 41, pp. 1690-1700, 2014.

[16] H. He, E.A. Garcia, "Learning from Imbalanced Data," IEEE Transactions on Knowledge And Data Engineering, vol. 21, no. 9, pp. 1263–1284, 2009.

[17] K-C. Khor, C-Y. Ting, and S. P-Amnuaisuk, “The effectiveness of sampling methods for the imbalanced network intrusion detection data set,” In Recent Advances on Soft Computing and Data Mining, pp. 613–622. Springer, 2014.

[18] N. Chawla, K. Bowyer, L. Hall, W.P. Kegelmeyer, SMOTE: synthetic minority over-sampling technique, J. Artif. Intell. Res. Vol. 16, pp. 321–357, 2002.

[19] N.V. Chawla, A. Lazarevic, L.O. Hall, K.W. Bowyer, “SMOTEBoost: improving prediction of the minority class in boosting, in: Proceedings of the 7th European Conference on Principles and Practice of Knowledge Discovery in Database, pp. 107–119, 2003.

[20] A. Lazarevi ´ c, J. Srivastava, V. Kumar, Tutorial: data mining for analysis of rare events: a case study in security, financial and medical applications, in: Proceeding of Pacific-Asia Conference Knowledge Discovery and Data Mining, 2004.

[21] M. Tavallaee, E. Bagheri, Wei Lu, and A. Ghorbani,“ A Detailed Analysis of the KDD CUP 99 Data Set ”, computational intelligence for security and defense applications,2009.

[22] R. Jain, “The Art of Computer Systems Performance Analysis: Techniques for Experimental Design, Measurement, Simulation, and Modeling” New York: Wiley-Interscience, 1991.

Rapid Control Prototyping and PIL Co-Simulation of a Quadrotor UAV Based on NI myRIO-1900 Board

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***Abstract*—In this paper, a new Computer Aided Design (CAD) methodology for the Processor-In-the-Loop (PIL) co-simulation and Rapid Control Prototyping (RCP) of a Quadrotor Vertical Take-Off and Landing (VTOL) type of Unmanned Arial Vehicle (UAV) is proposed and successfully implemented around an embedded NI myRIO-1900 target and a host PC. The developed software (SW) and hardware (HW) prototyping platform is based on the Control Design and Simulation (CDSim) module of LabVIEW environment and an established Network Streams data communication protocol. A dynamical model of the Quadrotor UAV, which incorporates the dynamics of vertical and landing flights and aerodynamic forces, is obtained using the Newton-Euler formalism. PID and Model Predictive Control (MPC) approaches are chosen as examples for experiment prototyping. These control laws, as well as the dynamical model of the Quad, are implemented and deployed as separate LabVIEW Virtual Instruments (VI) on the myRIO-1900 target and the host PC, respectively. Several demonstrative co-simulation results, obtained for a 3D LabVIEW emulator of the Quadrotor, are presented and discussed in order to improve the effectiveness of the proposed Model Based Design (MBD) prototyping methodology**

Keywords—Quadrotor UAV; modeling; Computer Aided Design; Model Based Design; Rapid Control Prototyping; PIL co-simulation; LabVIEW/CDSim; NI myRIO-1900; PID and MPC approaches

I. INTRODUCTION

The Unmanned Aerial Vehicles (UAV), particularly the Quadrotors ones [1]-[5], are flying robots without pilot which are able to conduct missions in autonomous or half-autonomous modes, also in hostile and disturbed environments. Among the tasks to be conducted with these robots are found military acknowledgment, monitoring missions and specially civilian missions such as the inspection of dams, border monitoring, the prevention of forest fires and so on [6]. This explains the interest shown by many researchers to study the flight dynamics and the advanced control laws real-world implementation of these kinds of vehicles.

The Quadrotor is a very promising concept of UAV aircrafts. It is a VTOL vehicle equipped with four rotors that are independently controlled [3]. The movement of such UAV results from changes in the speed of these rotors. The front and rear motors rotate counter-clockwise, while the left and right motors rotate clockwise. During its flight, a Quadrotor is subjected to external forces like the gusts of wind, gravity, viscous friction and others such as the thrust of rotors and body and propellers drag forces. Moments generated by gyroscopic effects of motors are also noted [1,3]. So, this mechanical structure and the nonlinear and coupled flight dynamics increase the complexity of the Quadrotor. The problem of its flight control and prototyping, i.e. the dynamics stabilization and path tracking, becomes challenging and allowed to be a popular topic in the field of robotics research. Control laws must be designed to work in a real-world scenario and over different flight conditions. Among many control approaches proposed for the dynamics stabilization and path tracking of Quadrotors, we note mainly the PID and Linear Quadratic [7]-[10], Sliding Mode (SMC) [11]-[13], backstepping [14], neural network [15] and Model Predictive (MPC) [16]-[19] control methods.

From the real-world practical point of view, such flight control algorithms must be verified and well prototyped before their definitive implementation on the Quadrotor. Sophisticated and embedded SW/HW solutions for this design stage are usually needed and a powerful platform for achieving both the rapid prototyping and final real-world implementation is very required. This problem can be efficiently handled thanks to the MDB and CAD concepts, especially with the related Processor-In-the-Loop (PIL) and/or Hardware-In-the-Loop (HIL) co-simulation methods. In this framework, the recent increased processing power of the Reconfigurable Inputs and Outputs (RIO) targets of the National Instruments (NI) Company, particularly the embedded myRIO-1900 devices [20], makes these platforms well suited to perform the advanced processing tasks required by complex and hard applications such as the rapid control prototyping, the HIL co-simulation and the final real-world implementation of various flight embedded controllers for QTW UAVs. Based on its suitable architecture and powerful onboard devices such as the three-axis accelerometer, analog IO extensions and Wi-Fi module, the myRIO-1900 target is a promised embedded solution for both prototyping and final real-world implementation platform of various and sophisticated flight controllers of aerial robots. Its associated LabVIEW Real-Time (RT) software tool takes also advantage of deterministic execution and the highest degree of reliability. So, this paper deals with the design and development of a new MBD solution for the PIL co-simulation and rapid control prototyping of a Quadrotor. Such a CAD methodology is built and successfully implemented around an embedded NI myRIO-1900 platform and a host PC. The software implementation is based on the Control Design and Simulation (CDSim) module of LabVIEW environment [21,22] and a set-up Network Streams-based data communication protocol. Both PID and MPC approaches are investigated as experiment examples in order to validate the proposed PIL co-simulation solution.

The remainder of this paper is organized as follows. Section 2 deals with the modeling of the Quadrotor for the vertical and landing flight dynamics using the Newton-Euler formalism. In Section 3, the developed NI myRIO-1900 based platform for the PIL co-simulation and control rapid prototyping of the rotorcraft is presented. All related software and hardware tools of such a CAD prototyping methodology are described. Section 4 is dedicated to the implementation and hardware co-simulation of the PID and MPC approaches, chosen as experiment examples for the Quadrotor attitude and altitude control prototyping. Several demonstrative results as well as our own developed LabVIEW graphical interfaces for rapid flight control prototyping are presented and discussed. Finally, concluding remarks end the paper in Section 5.

II. Modeling of the Quadrotor UAV

A. System description and aerodynamic forces

The studied Quadrotor is detailed with their body-frame $\boldsymbol{R}_B(O,\boldsymbol{x},\boldsymbol{y},\boldsymbol{z})$ and earth one $\boldsymbol{R}_E(o,\boldsymbol{e}_x,\boldsymbol{e}_y,\boldsymbol{e}_z)$ respectively, as shown in Fig. 1. Let denote by m the total mass of the Quadrotor, g the acceleration of the gravity and l the distance from the center of each rotor to the Center of Gravity (COG). The orientation of the Quadrotor is given by the rotation matrix $\mathcal{R}:\boldsymbol{R}_E \to \boldsymbol{R}_B$ which depends on the three Euler angles (ϕ,θ,ψ) and defined by the following equation:

$$\mathcal{R}(\phi,\theta,\psi)=\begin{bmatrix} c\psi c\theta & s\phi s\theta c\psi - s\psi c\theta & c\phi s\theta c\psi + s\psi s\phi \\ s\psi c\theta & s\phi s\theta s\psi + c\psi c\theta & c\phi s\theta s\psi - s\phi c\psi \\ -s\theta & s\phi c\theta & c\phi c\theta \end{bmatrix} \tag{1}$$

where $c(.)=\cos(.)$ and $s(.)=\sin(.)$.

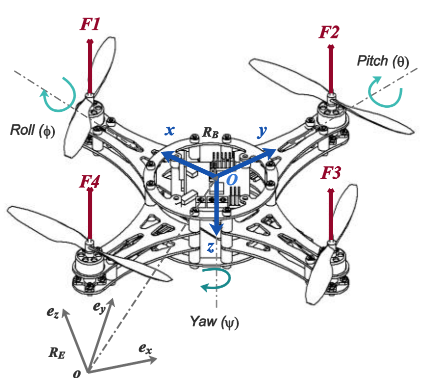

Fig. 1. Mechanical structure of the Quadrotor rotorcraft

Let consider the following model partitions of the Quadrotor naturally into translational and rotational coordinates:

$$\boldsymbol{\xi}=(x,y,z)^T \in \mathbb{R}^3, \quad \boldsymbol{\eta}=(\phi,\theta,\psi)^T \in \mathbb{R}^3 \tag{2}$$

where $\boldsymbol{\xi}=(x,y,z)^T$ denotes the position vector of the COG of the Quadrotor relative to its fixed earth-frame, $\boldsymbol{\eta}=(\phi,\theta,\psi)^T$ denotes the attitude of the Quadrotor given by the Euler angles for rolling $\phi\in[-\pi/2,\pi/2]$, pitching $\theta\in[-\pi/2,\pi/2]$ and yawing $\psi\in[-\pi,\pi]$ motions.

Let a vector $\boldsymbol{\nu}=(u,v,w)^T$ denote the linear velocity of the UAV in the earth-frame $\boldsymbol{R}_E$, while the vector $\boldsymbol{\vartheta}=(p,q,r)^T$ represents its angular velocity in $\boldsymbol{R}_B$ frame. The kinematic equations of rotational and translational movements are obtained, respectively, as follows [12,13]:

$$\begin{pmatrix}\dot\phi\\ \dot\theta\\ \dot\psi\end{pmatrix}=\begin{pmatrix}1 & \sin\phi\tan\theta & \cos\phi\tan\theta\\ 0 & \cos\phi & -\sin\phi\\ 0 & \sin\phi\sec\theta & \cos\phi\sec\theta\end{pmatrix}\begin{pmatrix}p\\ q\\ r\end{pmatrix} \tag{3}$$

$$\boldsymbol{\nu}_e=\mathcal{R}(\phi,\theta,\psi)\boldsymbol{\nu}_B \tag{4}$$

where $\boldsymbol{\nu}_e$ and $\boldsymbol{\nu}_B$ are linear velocities of the mass center expressed in the earth-frame and body-frame, respectively.

Each motor of the Quadrotor produces the force F_i which is proportional to the square of the angular speed. The trust force generated by the ith rotor of Quadrotor is given by:

$$F_i=\frac{1}{2}\rho\Lambda C_T r^2\Omega_i^2=b\Omega_i^2 \tag{5}$$

where ρ is the air density, r and Λ are the radius and the section of the propeller respectively, C_T is the aerodynamic thrust coefficient.

The aerodynamic drag torque, caused by the drag force at the propeller of the ith rotor and opposed the motor torque, is defined as follows:

$$\delta_i=\frac{1}{2}\rho\Lambda C_D r^2\Omega_i^2=d\Omega_i^2 \tag{6}$$

where C_D is the aerodynamic drag coefficient.

The pitch torque is a function of the difference (F_3-F_1), the roll torque is proportional to the term (F_4-F_2) and the yaw one is the sum of all reactions torques generated by the four rotors and due to the shaft acceleration and propeller drag. All these pitching, rolling and yawing torques are defined respectively as follows:

$$\Gamma_\theta=l(F_3-F_1) \tag{7}$$

$$\Gamma_{\phi} = l\left(F_4 - F_2\right) \quad (8)$$

$$\Gamma_{\psi} = \lambda\left(F_1 - F_2 + F_3 - F_4\right) \quad (9)$$

where λ is a proportional coefficient.

Two gyroscopic effects torques, due to the motion of the propellers and the Quadrotor body, are additively provided. These moments are given respectively by:

$$M_{gp} = \sum_{i=1}^{4} \mathbf{\Omega} \wedge \left(0, 0, J_r \left(-1\right)^{i+1} \Omega_i\right)^T \quad (10)$$

$$M_{gb} = \mathbf{\Omega} \wedge \boldsymbol{J}\mathbf{\Omega} \quad (11)$$

where $\mathbf{\Omega}$ is the vector of angular velocities in the fixed earth-frame and $\boldsymbol{J} = diag\left(I_{xx}, I_{yy}, I_{zz}\right)$ is the inertia matrix of the Quadrotor, J_r denotes the z-axis inertia of the propellers rotors.

The Quadrotor is controlled by independently varying the speed of the four rotors. Hence, these control inputs are defined as follows:

$$\begin{pmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{pmatrix} = \begin{pmatrix} F \\ \Gamma_{\phi} \\ \Gamma_{\theta} \\ \Gamma_{\psi} \end{pmatrix} = \begin{pmatrix} b & b & b & b \\ 0 & -lb & 0 & lb \\ -lb & 0 & lb & 0 \\ d & -d & d & -d \end{pmatrix} \begin{pmatrix} \Omega_1^2 \\ \Omega_2^2 \\ \Omega_3^2 \\ \Omega_4^2 \end{pmatrix} \quad (12)$$

where $\Omega_{1,2,3,4}$ are the angular speeds of the four rotors, respectively.

From Eq. (12), it can be observed that the input u_1 denotes the total thrust force on the Quadrotor body in the z-axis, the inputs u_2 and u_3 represent the roll and pitch torques, respectively. The input u_4 represents a yawing torque.

B. Modeling with Newton-Euler Formalism

While using the Newton-Euler formalism for modeling, the Newton's laws lead to the following motion equations of the Quadrotor:

$$\begin{cases} m\ddot{\boldsymbol{\xi}} = \boldsymbol{F}_{th} + \boldsymbol{F}_d + \boldsymbol{F}_g \\ \boldsymbol{J}\dot{\mathbf{\Omega}} = M - M_{gp} - M_{gb} - M_a \end{cases} \quad (13)$$

where $\boldsymbol{F}_{th} = \mathcal{R}\left(\phi, \theta, \psi\right)\left(0, 0, \sum_{i=1}^{4} F_i\right)^T$ denotes the total thrust force of the four rotors, $\boldsymbol{F}_d = diag\left(\kappa_1, \kappa_2, \kappa_3\right)\boldsymbol{\nu}^T$ is the air drag force which resists to the Quadrotor motion, $\boldsymbol{F}_g = \left(0, 0, mg\right)^T$ is the gravity force, $M = \left(\Gamma_{\phi}, \Gamma_{\theta}, \Gamma_{\psi}\right)^T$ represents the total rolling, pitching and yawing torques, M_{gp} and M_{gb} are the gyroscopic torques and $M_a = diag\left(\kappa_4, \kappa_5, \kappa_6\right)\boldsymbol{\vartheta}^T$ is the torque resulting from aerodynamic frictions.

Substituting the position vector and the forces expressions into the Eq. (13), we have the following translational dynamics of the Quadrotor:

$$\begin{cases} \ddot{x} = \dfrac{1}{m}\left(c\phi c\psi s\theta + s\phi s\psi\right)u_1 - \dfrac{\kappa_1}{m}\dot{x} \\ \ddot{y} = \dfrac{1}{m}\left(c\phi s\psi s\theta - s\phi c\psi\right)u_1 - \dfrac{\kappa_2}{m}\dot{y} \\ \ddot{z} = \dfrac{1}{m}c\phi c\theta u_1 - g - \dfrac{\kappa_3}{m}\dot{z} \end{cases} \quad (14)$$

From the second part of Eq. (13), and while substituting each moment by its expression, we deduce the following rotational dynamics of the rotorcraft:

$$\begin{cases} \ddot{\phi} = qr\dfrac{I_y - I_z}{I_x} - \dfrac{J_r}{I_x}\Omega_r q - \dfrac{\kappa_4}{I_x}p + \dfrac{1}{I_x}u_2 \\ \ddot{\theta} = pr\dfrac{I_z - I_x}{I_y} + \dfrac{J_r}{I_y}\Omega_r p - \dfrac{\kappa_5}{I_y}q + \dfrac{1}{I_y}u_3 \\ \ddot{\psi} = pq\dfrac{I_x - I_y}{I_z} - \dfrac{\kappa_6}{I_z}r + \dfrac{1}{I_z}u_4 \end{cases} \quad (15)$$

According to the above established Eq. (14) and Eq. (15), $X = \left(\phi, \dot{\phi}, \theta, \dot{\theta}, \psi, \dot{\psi}, x, \dot{x}, y, \dot{y}, z, \dot{z}\right)^T \in \mathbb{R}^{12}$ is retained as the state vector of the Quadrotor nonlinear model. Note that $\kappa_{1,2,\ldots,6}$ are the aerodynamic friction and translational drag coefficients, $\Omega_r = \Omega_1 - \Omega_2 + \Omega_3 - \Omega_4$ is the overall residual rotor angular velocity.

III. Proposed CAD Methodology for Rapid Control Prototyping

A. Rapid control prototyping platform

An advanced MBD platform for control algorithms verification and prototyping must make easy the practical implementation with the same used hardware target and software tools. In this paper, the hardware setup of the proposed MBD methodology for rapid prototyping and PIL co-simulation of QTW UAVs is depicted in Fig. 2.

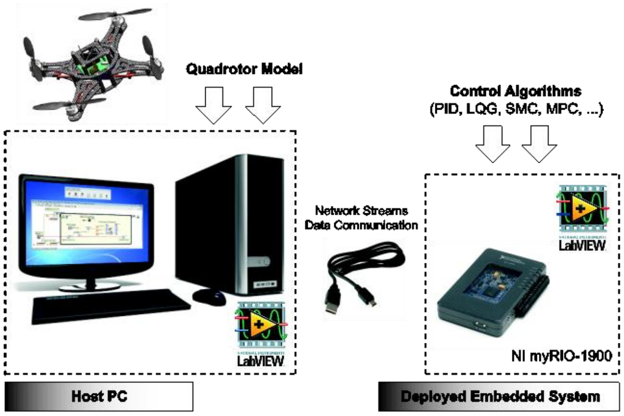

Fig. 2. Synoptic scheme of the NI myRIO-1900 based PIL co-simulation platform

The developed SW/HW solution is based mainly on the use of an embedded myRIO-1900 platform from National Instruments Company. Well-suitable for complex processing and real-time computing, this NI portable and RIO target is associated to a host PC with LabVIEW CDSim, myRIO 2015 and Robotics environments. After prototyping phase, the myRIO-1900 device operates autonomously to execute a LabVIEW control project which is deployed on its RT dual-core processor. Thanks to its powerful tools, LabVIEW software environment simplifies construction and prototyping of designed control systems and provides the ability to implement a variety of control algorithms.

B. NI my RIO-1900 board based implementation

The main component of the proposed PIL platform for rapid prototyping of the QTW vehicle is the embedded and reconfigurable NI myRIO-1900 board, depicted in Fig. 3. Featuring the NI industry-standard reconfigurable I/O technology, this hardware target is the enclosed version of myRIO platforms which presents three I/O connectors, wireless capabilities and a dual-core ARM RT Cortex-A9 processor with 667 MHz frequency speed [20]. The NI myRIO-1900 platform is also equipped with 256 MB of nonvolatile memory and 512 MB of DDR3 RAM memory. Running a real-time OS as well as a customizable FPGA circuit with the Xilinx SoC Zynq-710 architecture, this embedded target provides differential and single-ended (referenced 0-5V and ±10V) 10 Analog Inputs (AI) and 6 Analog Outputs (AO), 40 general-purpose Digital I/O lines (DIO), with 3.3V output, 3.3 V/5 V-compatible, audio, and power output in a compact embedded device.

The NI myRIO-1900 platform contains an onboard three-axis accelerometer with a range of ±8g, a resolution of 12 bits and a sample rate of 800 S/s. This integrated device samples each axis continuously and updates a readable register with the result and remains very suitable for the UAV control prototyping and implementation framework. Connected to a host computer over USB and wireless 802.11b, g, n possibilities [20], the myRIO-1900 is equipped with a box Wi-Fi module which can be used for remote control of such UAV aircrafts. Adaptable for LabVIEW programming level and thanks to its onboard devices (PWM, SPI, I2C, encoder, etc.), its reduced physical dimensions and low weight, the myRIO-1900 provides an affordable tool that helps to design and prototype advanced flight control algorithms and real-world design projects of UAV guidance.

Fig. 3. Embedded NI myRIO-1900 Board

C. LabVIEW CDSim and myRIO software tools

The LabVIEW CDSim, as a sophisticated LabVIEW add-on from NI Company [21], leads to identify and simulate online and offline dynamic systems, analyze open-loop model behavior, design closed-loop controllers and estimators, and deploy digital control systems implementation on NI hardware platforms. As depicted in Fig. 4, the CDSim tool provides various libraries for control design and simulation of dynamic systems.

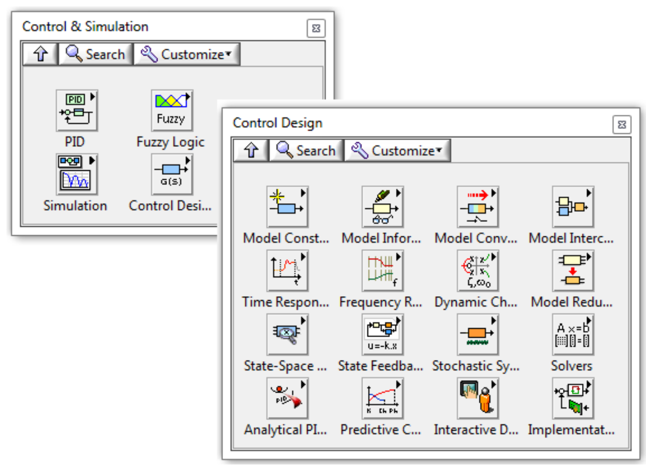

Fig. 4. Control Design & Simulation palettes of the LabVIEW/CDSim module

When integrated with others NI built-in tools, such as LabVIEW MathScript RT module, the CDSim module performs textual mathematics and algorithm design in LabVIEW using the *.m file based syntax. Furthermore, the usability of LabVIEW CDSim module can be also expanded with LabVIEW System Identification toolkit to find empirical models from real plant stimulus-response information, with LabVIEW PID and Fuzzy Logic toolkit for design and tuning various PID and fuzzy control structures, and with LabVIEW Statechart module for event-based control prototyping [21]. Once the control algorithms are designed, it is easy to deploy dynamic systems to real-time hardware targets without the need to generate code by using the LabVIEW Real-Time and LabVIEW FPGA modules. The LabVIEW myRIO toolkit can be instead used while working with NI myRIO platforms as shown in Fig. 5.

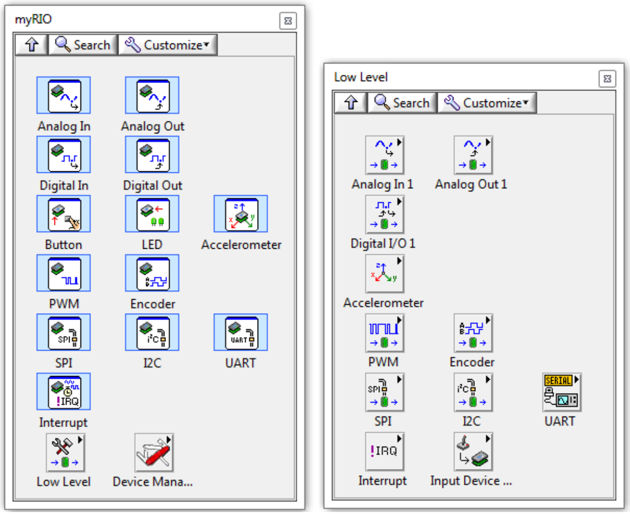

Fig. 5. NI myRIO low level VIs and advanced IO palettes

IV. Hardware Implementation and Co-Simulatio Results

In order to show the effectiveness of the proposed PIL co-simulation methodology, PID and MPC approaches are investigated for prototyping tests. For the discrete-time control laws implementation, a sampling time equal to 0.01 sec is used. The physical parameters of Table I are used for controller's synthesis and PIL co-simulation stages. The setpoints for the attitude and position dynamics control are applied by external potentiometers connected to the appropriate analog inputs of the myRIO-1900 board.

TABLE I. Quadrotor Vehicle Model Parameters

Parameters	**Values**
Mass m	0.650 (kg)
Rotor distance to COG l	0.23 (m)
Lift coefficient b	2.9e-05 (N/rad/s)
Drag propellers coefficient d	3.23e-07 (Nm/rad/s)
Body inertias I_{xx}, I_{yy} and I_{zz}	0.0075, 0.0075, 0.013 (kg.m^2)
Propellers inertia along z-axis J_r	6.00e-05 (kg.m^2)
Translational drag coefficients κ_1, κ_2 and κ_3	5.57e-04, 5.57e-04, 6.35e-04 (N/rad/s)
Aerodynamic friction coefficients κ_4, κ_5 and κ_6	5.57e-04, 5.57e-04, 6.35e-04 (N/m/s)
Acceleration of the gravity g	9.81 (m/s^2)

A. PID control prototyping

A typical structure of PID controller, given by Eq. (16), is used for the stabilization of the altitude and attitude dynamics of the QTW [23]:

$$u(t) = K_p\left[e(t) + \frac{1}{T_i}\int_0^t e(\tau)\,d\tau + T_d\,\frac{de(t)}{dt}\right] \tag{16}$$

The error signal $e(t)$ is used to generate the proportional, integral and derivative actions of the designed controller. The empirical Ziegler-Nichols based method is firstly adopted to compute the appropriate values of the PID parameters [23]. Then, such parameters can be tuned further thanks to the developed PIL co-simulation interface. Four PID control laws, for each altitude z, roll ϕ, pitch θ and yaw ψ dynamics, will then generated as control inputs for the Quadrotor according to Eq. (12).

For the PIL and HIL applications, communication between VIs and exchange data between them is always a critical part of a LabVIEW RT project. Such applications typically function as "data servers" and operate with the principle of the LabVIEW Server/Client architecture [22]. In such architecture, a host PC acts as a data "Server" in order to provide information to the myRIO NI-1900 platform as the "Client". For such a communication protocol building and management, different data communication mechanisms, such as Network-Published Shared Variables, Raw Ethernet (TCP/UDP) and Network Streams have been proposed [22].

In our PIL co-simulation case, we need sending measures of Quadrotor states from the host PC VI and receive such data in the controller VI, deployed on the myRIO target, to provide in turn control signals and setpoints to the Quadrotor. Thus, we choose the Network Streams approach that best meets our mentioned needs. For setting-up a network stream for the proposed PIL solution, the LabVIEW diagrams of Fig. 6 and Fig. 7 are implemented on the host PC (Quadrotor model) and myRIO deployed embedded target (PID controller), respectively. We develop later the LabVIEW diagram for the MPC approach. Two control & simulation loops from the LabVIEW CDSim module are used to build separately the Quadrotor and control algorithms models. Each model can be then implemented inside these given loops.

The implemented LabVIEW front panels for the PID controller prototyping and the dynamic model of the Quadrotor are shown in Fig. 8 and Fig. 9, respectively. Such implementations are made separately on two VIs which are physically deployed on the host PC and the embedded myRIO-1900 platform, respectively. This proposed HW/SW solution leads to the hardware co-simulation results of Fig. 10 and Fig. 11 for the attitude and altitude dynamics control prototyping, respectively. These demonstrative curves show the effectiveness of such an advanced PIL solution based on the embedded NI myRIO-1900 platform.

Later, we give in Fig. 17 some flight illustrations in the 3D frame, obtained for the MPC based control prototyping of the emulated Quadrotor rotorcraft.

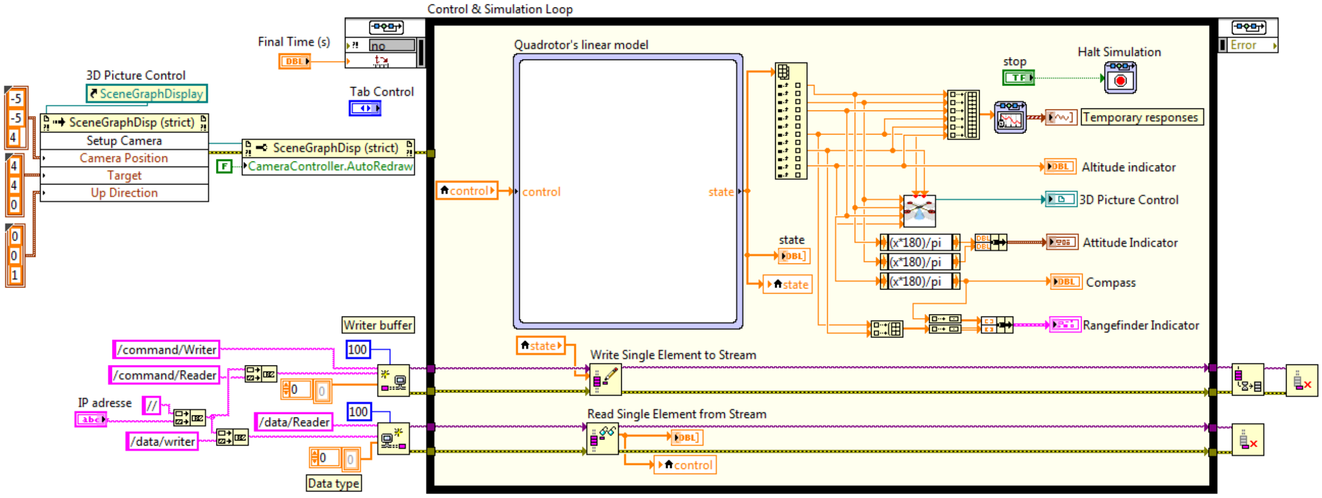

Fig. 6. LabVIEW diagram for the Network Streams “Server” based implementation of the Quadrotor model

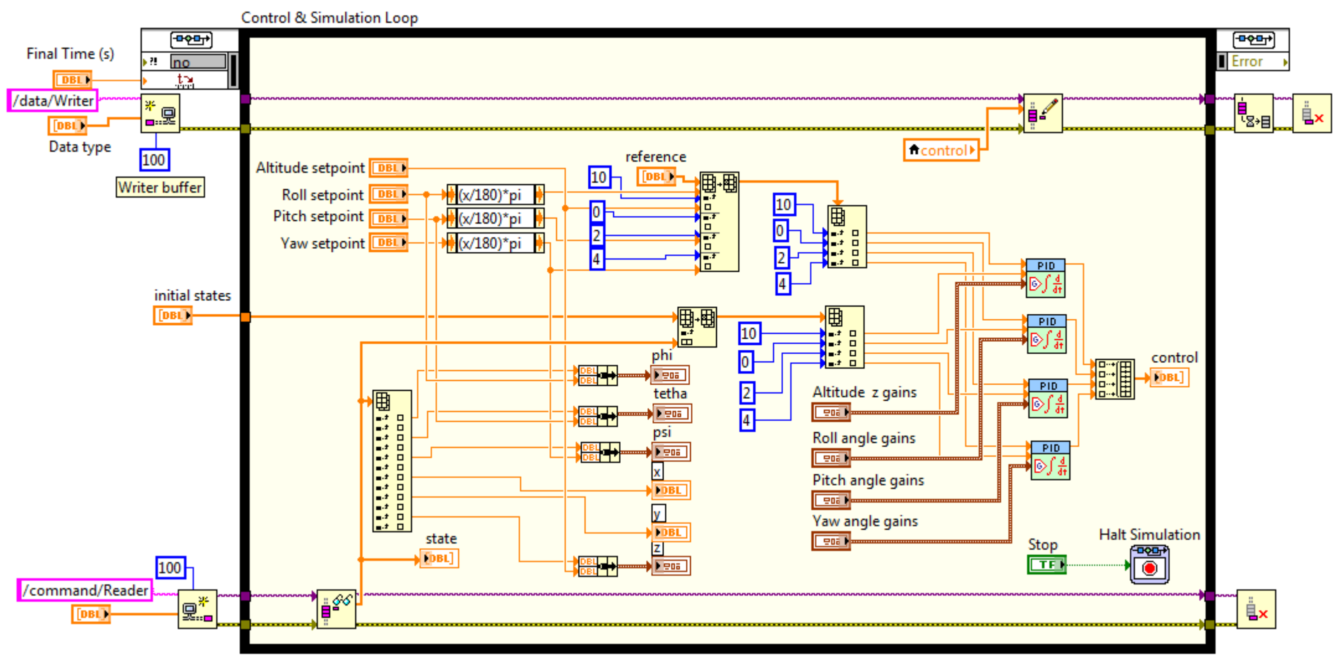

Fig. 7. LabVIEW diagram for the Network Streams “Client” based implementation of the PID controller algorithm

B. *MPC control prototyping*

This section is devoted to the rapid MPC prototyping of the Quadrotor while using the same PIL co-simulation platform. The main elements of the discrete-time MPC are the plant input, the controlled output and the reference trajectory which are denoted by $u \in \mathbb{R}$, $y \in \mathbb{R}$, and $r \in \mathbb{R}$, respectively. The plant model determines the predicted plant outputs on the prediction horizon N_p. The optimization algorithm is aimed at determining the control sequence given by $\{u(k-1+i), i=1,2,\ldots,N_c\}$ for the control horizon N_c. Only the first element $u^*(k)$ of the optimized control sequence is applied to the plant and the control input is updated at each sampling instant.

At every sampling time and for a specified prediction and control horizons, the MPC controller, designed and implemented on the LabVIEW/CDSim environment, attempts to minimize the following cost function [24,25,21]:

$$J_{MPC}(k) = \sum_{i=1}^{N_p} \hat{e}(k+i\,|\,k)^T \boldsymbol{Q} \hat{e}(k+i\,|\,k) + \sum_{i=1}^{N_c} \left[\Delta u^T(k+i\,|\,k) \boldsymbol{R} \Delta u(k+i\,|\,k) \right] \tag{17}$$

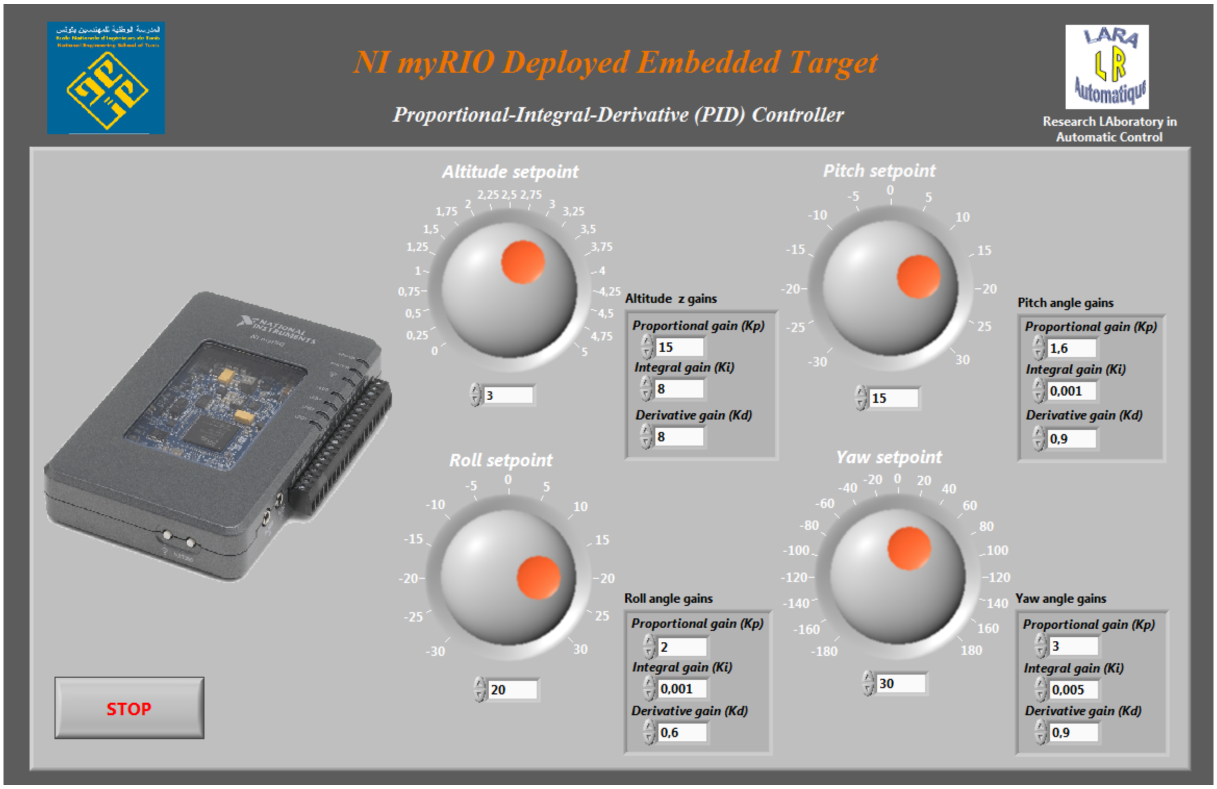

Fig. 8. LabVIEW Front Panel for the rapid PID control prototyping: VI deployed on the myRIO-1900 target

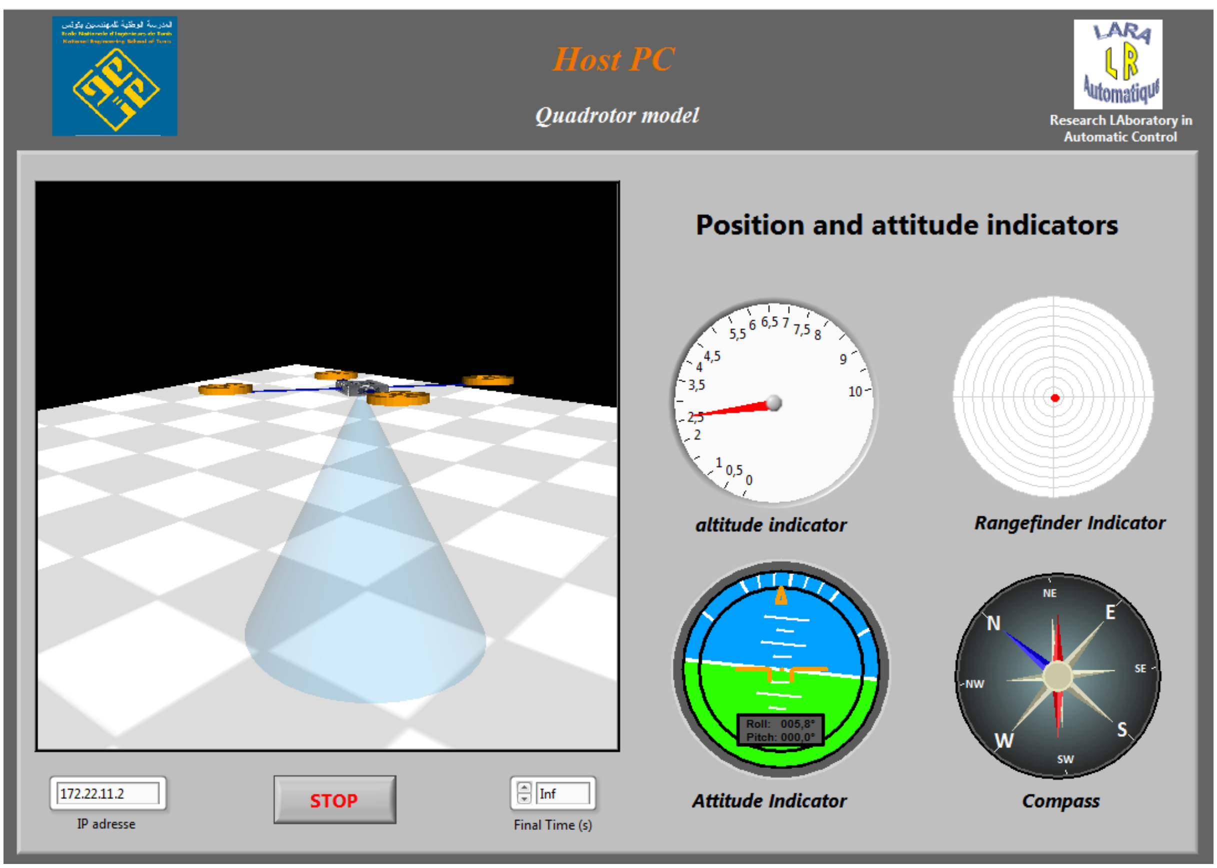

Fig. 9. LabVIEW Front Panel for the Quadrotor dynamic model implementation: VI deployed on the host PC

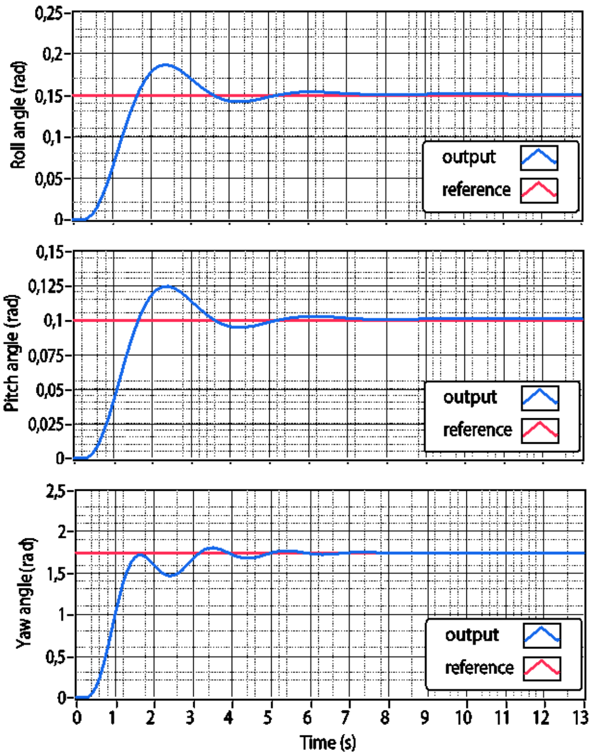

Fig. 10. PID prototyping results for the Quadrotor attitude

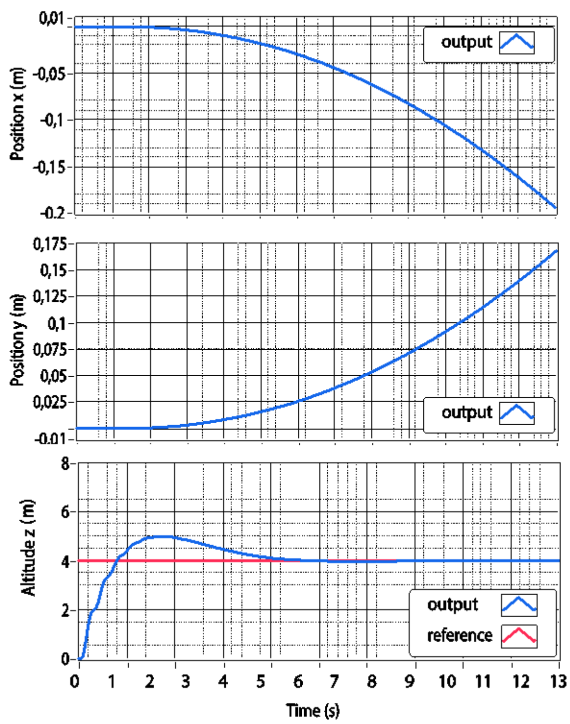

Fig. 11. PID prototyping results for the Quadrotor altitude

In Eq. (17), $\hat{e}(k+i\,|\,k)=\hat{y}(k+i\,|\,k)-r(k+i\,|\,k)$, $\hat{y}(k+i\,|\,k)$, $r(k+i\,|\,k)$ and $\Delta u(k+i\,|\,k)$ are the predicted plant output, the output setpoint profile and the predicted increment of change in control action, respectively. The terms $\boldsymbol{Q}=\boldsymbol{Q}^T>0$ and $\boldsymbol{R}=\boldsymbol{R}^T>0$ are the weighting matrices. Minimizing the cost function (17) is usually subject to the operational constraints on the control action, its rate of change and plant output signals [21].

To create an MPC controller under the LabVIEW/CDSim environment, the CD Create MPC Controller VI of Fig. 12 is used. This VI bases the MPC controller on a state-space model of the controlled plant. The prediction and control horizons must be provided in the MPC Controller Parameters input of the CD Create MPC Controller VI. These predictive control parameters, as shown in Fig. 1, are fixed for the duration of the execution of the controller. MPC State Estimator Parameters of this VI specifies the parameters of the state estimator that the MPC Controller uses to estimate the states of the plant.

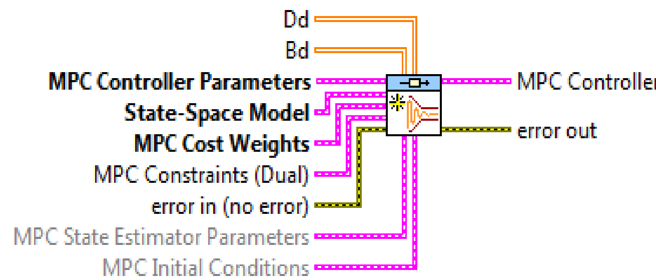

Fig. 12. LabVIEW CD Create MPC Controller VI

Furthermore, the created MPC controller is now implemented either in the co-simulation, or in a real-world scenario, while using the CD Implement MPC Controller VI of Fig. 13 within a timed or simulation loops.

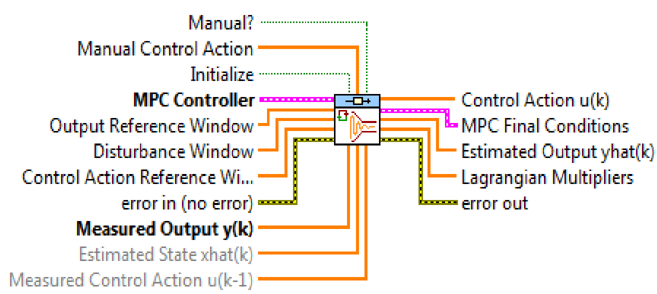

Fig. 13. LabVIEW CD Implement MPC Controller VI

After the MPC algorithm implementation for the studied Quadrotor, we give in Fig. 14 the developed LabVIEW diagram for the rapid MPC prototyping. The demonstrative co-simulation results are depicted in Fig. 15 and Fig. 16 for the position and attitude control prototyping, respectively. In order to show the controlled flight behavior of the co-simulated Quadrotor, a 3D prototype is built and animated under LabVIEW environment as depicted in Fig. 17. It can be observed that such a 3D prototype behaves properly in real-time according to the variation of the control setpoint inputs. This result improves further the effectiveness and the validity of our proposed HW/SW co-simulation solution.

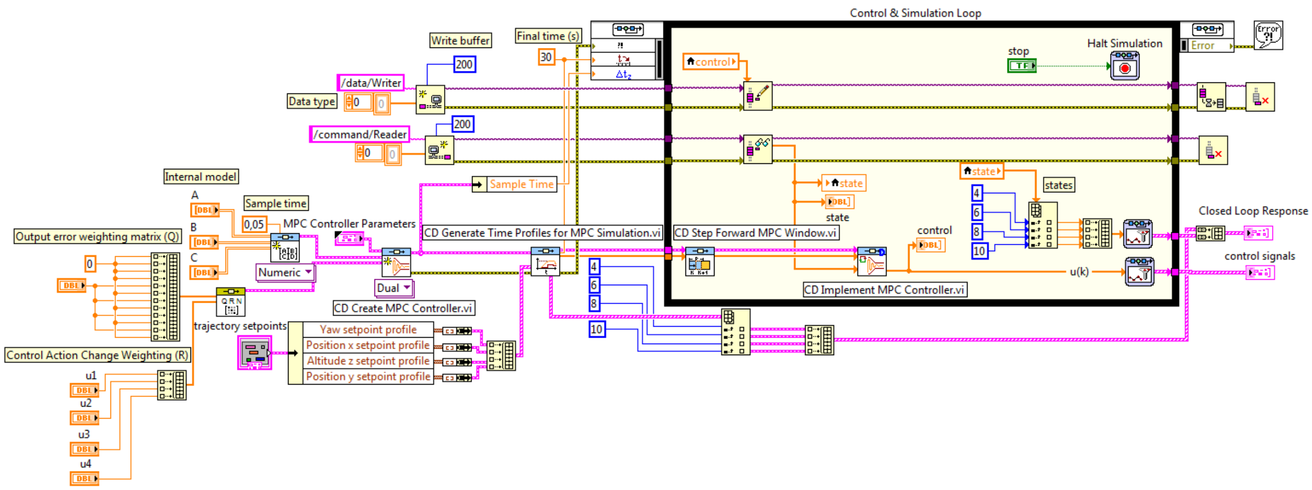

Fig. 14. LabVIEW diagram for the Network Streams “Client” based implementation of the MPC algorithm model

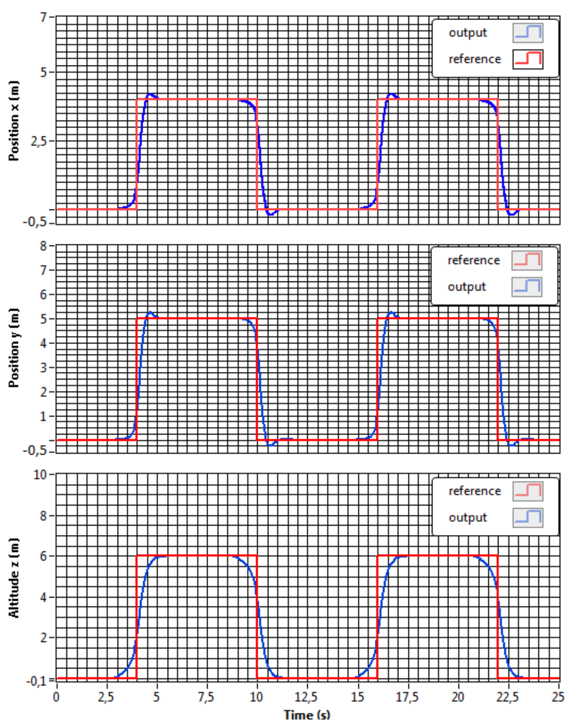

Fig. 15. MPC prototyping results for the Quadrotor position

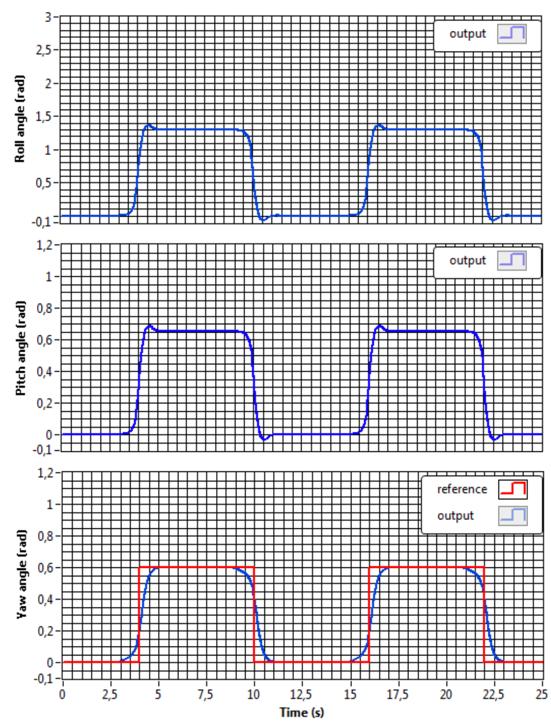

Fig. 16. MPC prototyping results for the Quadrotor attitude

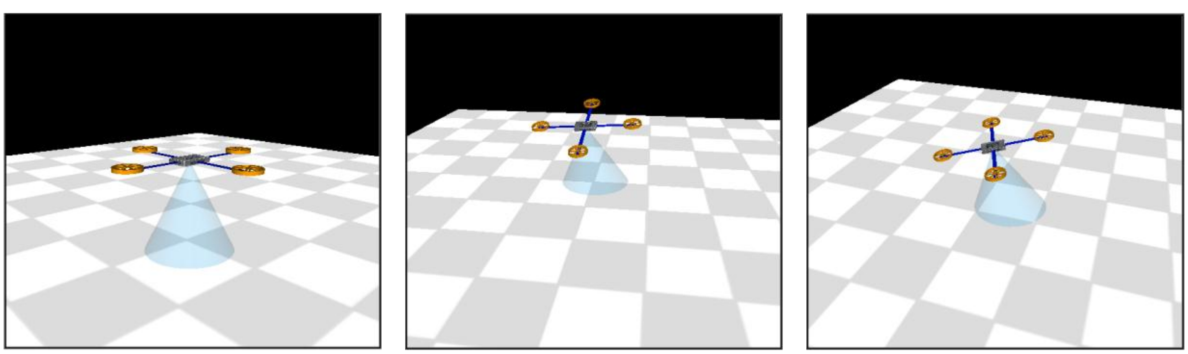

Fig. 17. Flight motion illustrations of the co-simulated Quadrotor in a 3D frame

V. Conclusion

In this paper, a new CAD methodology for PIL co-simulation is proposed and successfully implemented for the rapid flight control prototyping of a Quadrotor UAV. The proposed SW/HW solution is based on an embedded NI myRIO-1900 platform and a host PC equipped with the LabVIEW/CDSim graphical programming environment. An efficient set-up Network Streams data communication protocol is further established for such MBD platform. The nonlinear dynamic model of the Quadrotor as well as those of PID and MPC algorithms are implemented and deployed on two separate VIs within a LabVIEW RT myRIO project thanks to the developed and given LabVIEW patterns for the host PC and deployed embedded target parts. All hardware co-simulation results, obtained for a built 3D prototype of the studied rotorcraft, show the effectiveness of our proposed myRIO-based prototyping platform. These results improve further the low cost and simplicity of the future real-world implementation of the prototyped control laws while using the same embedded NI myRIO-1900 platform.

References

[1]. R. Lozano (Ed.), *Unmanned aerial vehicles: Embedded control*, John Wiley & Sons, ISTE, UK, 2010.

[2]. R. Austin, *Unmanned Aircraft Systems: UAVs design, development and deployment*, 1st edition, John Wiley & Sons Ltd, London, 2010.

[3]. K. Nonami, F. Kendoul, S. Suzuki, W. Wang and D. Nakazawa, Autonomous Flying Robots: Unmanned *Aerial Vehicles and Micro Aerial Vehicles*, Springer, New York, 2010.

[4]. F. Torres, A. Rabhi, D. Lara, G. Romero and C. Pégard, Fuzzy State Feedback for Attitude Stabilization of Quadrotor, *International Journal of Advanced Robotic Systems*, vol. 13, no. 2, DOI: 10.5772/61934, 2016.

[5]. T. Espinoza, A. Dzul and M. Llama, Linear and Nonlinear Controllers Applied to Fixed-Wing UAV, *International Journal of Advanced Robotic Systems*, vol. 10, DOI: 10.5772/53616, 2013.

[6]. K.P. Valavanis (Ed.), *Advances in Unmanned Aerial Vehicles: State of the Art and the Road to Autonomy*, 1st edition, Springer Netherlands, New York, 2007.

[7]. L.M. Argentim, W.C. Rezende, P.E. Santos and R.A. Aguiar, PID, LQR and LQR-PID on a Quadcopter platform, In *the 2013 International Conference on Informatics, Electronics & Vision*, pp. 1-6, Dhaka, Bangladesh, May 2013.

[8]. S. Khatoon, D. Gupta, and L.K. Das, PID & LQR control for a Quadrotor: Modeling and simulation, In *the 2014 International Conference on Advances in Computing, Communications and Informatics*, pp. 796-802, New Delhi, September 2014.

[9]. J. Han, L. Di, C. Coopmans and Y.Q. Chen, Pitch Loop Control of a VTOL UAV Using Fractional Order Controller, *International Journal of Intelligent & Robotic Systems*, vol. 73, no. 1, pp. 187-195, 2014.

[10]. H. Liu, Y. Bai, G. Lu, Z. Shi and Y. Zhong, Robust Tracking Control of a Quadrotor Helicopter, *International Journal of Intelligent & Robotic Systems*, vol. 75, no. 3, pp. 595-608, 2014.

[11]. L. Besnard, Y.B. Shtessel and B. Landrum, Quadrotor vehicle control via sliding mode controller driven by sliding mode disturbance observer, *Journal of the Franklin Institute*, vol. 349, no. 2012, pp. 658-684, 2011.

[12]. E-H. Zheng, J-J. Xiong and J-L. Luo, Second order sliding mode control for a Quadrotor UAV, *ISA Transactions*, vol. 53, no. 4, pp. 1350-1356, 2014.

[13]. J-J. Xiong and E-H. Zheng, Position and attitude tracking control for a Quadrotor UAV, *ISA Transactions*, vol. 53, no. 3, pp. 725-731, 2014.

[14]. G.V. Raffo, M.G. Ortega and F.R. Rubio. Backstepping/nonlinear H_∞ control for path tracking of a Quadrotor unmanned aerial vehicle, In *the American control conference*, pp. 3356-3361, Seattle, 2008.

[15]. X. Lei, S.S. Ge and J. Fang, Adaptive Neural Network Control of Small Unmanned Aerial Rotorcraft, *International Journal of Intelligent & Robotic Systems*, vol. 75, no. 2, pp. 331-341, 2014.

[16]. K. Alexis, G. Nikolakopoulos and A. Tzes, Model predictive Quadrotor control: attitude, altitude and position experimental studies, *IET Control Theory Applications*, vol. 6, no. 12, pp. 1812-1827, 2012.

[17]. G.V. Raffo, M.G. Ortegaand F.R. Rubio. An integral predictive/nonlinear H_∞ control structure for a Quadrotor helicopter, *Automatica*, vol. 46, no. 2010, pp. 29-39, 2009.

[18]. N. Slegers, J. Kyle and Mark Costello, Nonlinear Model Predictive Control Technique for Unmanned Air Vehicles, *Journal of Guidance, Control and Dynamics*, vol. 29, no. 5, pp. 1179-1188, 2006.

[19]. R.V. Lopes, P.H. Rodrigues, G. Borges and J. Ishihara, Model Predictive Control applied to tracking and attitude stabilization of a VTOL Quadrotor aircraft, *ABCM Symposium Series in Mechatronics*, vol. 5, pp. 176-185, 2012.

[20]. National Instruments, *NI myRIO-1900: User Guide and Specifications*, 376047A-01, www.ni.com, Accessed on 05/September/2015.

[21]. National Instruments, *LabVIEW Control Design User Manual*, 371057G-01, www.ni.com, Accessed on 13/July/2015.

[22]. National Instruments, *NI LabVIEW for Compact RIO Developer's Guide*, www.ni.com, Accessed on 16/September/2015.

[23]. K.J. Åström and T. Hägglund, *PID Controllers: Theory, Design, and Tuning*, Instrument Society of America, Research Triangle Park, North Carolina, 1995.

[24]. J.B. Rawlings, D.Q. Mayne, *Model Predictive Control: Theory and Design*, Nob Hill Publishing, Madison, USA, 2013.

[25]. J.A. Rossiter, *Model Based Predictive Control: A practical Approach*, Control Series, CRC Press, New York, 2004.

Ontology based Intrusion Detection System in Wireless Sensor Network for Active Attacks

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***Abstract*—WSNs are vulnerable to attacks and have deemed special attention for developing mechanism for securing against various threats that could effect the overall infrastructure. WSNs are open to miscellaneous classes of attacks and security breaches are intolerable in WSNs. Threats like untrusted data transmissions, settlement in open and unfavorable environments are still open research issues. Safekeeping is an essential and complex requirement in WSNs. These issues raise the need to develop a security-based mechanism for Wireless Sensor Network to categorize the different attacks based on their relevance. A detailed survey of active attacks is highlighted based on the nature and attributes of those attacks. An Ontology based mechanism is developed and tested for active attacks in WSNs.**

Keywords—Semantics; Wireless Sensor Network; Intrusion detection and prevention system; ontologies

I. Introduction

Wireless sensor nodes have reorganized not only the process but also the strategy structure of any system; either identifying any person in moving groups, or tankers in the battle field, pollution in surroundings, determining the stream of traffic on transportations, as well as mark out the worker's position in office block. Several WSNs are used in critical applications and consequently they need active security alerts [2][3][16] wireless sensor Network offered great suppleness in data broadcast but there are a quantity of matters of security in sensors node owing to restricted resources such as processing unit and power . Invader can take passive and active attacks skills. Possible attack in WSN can be DoS, Jamming, Sybil, Wormhole, Tempering, Selective Forwarding, Sinkhole, Hello Flood Attacks, and Acknowledgment Spoofing.

WSN has most important challenges in operating security arrangements due to wireless medium, Ad-Hoc Deployment, Unreliable Communication, Unreliable Transfer, Conflicts Latency, Unattended Operation, Exposure to Physical Attacks Managed Remotely. In WSN security requirement can be achieved by applying Authentication, Integrity, and Data Confidentiality, Data freshness, Availability, Self-Organization, Time Synchronization, Secure Localization, Nonrepudiation. This work implements ontologies to improve the IDS in WSN.

Ontology can be used to classify and infer new knowledge by identifying the relevance among different attacks,

The work focuses on categorization of new nodes in ontologies and then these relations of nodes are then applied to detect malicious activities.

After placement of the WSN, BS gathers routing and positioning information of sensor nodes. At earlier stage of IDS select the cluster head node highest energy based, two agents that have low energy status in respect of CH and starts the abstract relationships of each node in the ontology. The broadcast of every node will be governed by its association to the ontology. The intruder cannot then make-believe that nasty nodes are legal nodes.

The proposed architecture is divided into five sections. (1) Data routing information, attack threshold/feature. (2) Data gathering and monitoring cell depending on the environment. (3) Agent system that collect data from monitoring/ collection cell and check its status, also decide the behavior of data. (4) Knowledge Management System

Ontology, SWRL Rules, Attack Signature section construct ontology properties, set threshold relationship match SWRL Rules and attack signature. (5) IDS Section Analysis data & decide which attack type and produce alert system.

This paper is structured as Section I introduction. Section II Semantic based Architecture. Section III Approach used to detect attack in WSN. Section IV Related Work. Section V Proposed methodology. Section VI Proposed Security Ontology. Section VII Result and evaluation. Section VIII conclusion and future direction.

A. *Major Challenges in Sensor Network Security*

The natural surroundings of all sorts of networks appear the unique contests in manipulating security schemes. WSNs is a distinct sort of network which has additional restrictions than any other old networks [4][8].

Wireless Medium

The wireless medium is basically unsecure due to its broadcasting nature. Thus any challenging can straightforwardly stopped, altered and rerun the broadcast [8].

Ad-Hoc Deployment

The placement of ad-hoc in SNs results that not fix discrete structure. The network topology altered frequently and difficulty to identify.

Unreliable Communication

Major warning on sensor security is unreliable communication.

Unreliable Transfer

The transmitting of packets is unreliable due to connectionless channeling is used in WSNs.

Conflicts

Due to broadcast nature of WSNs might be substandard communication while a trustworthy channel exists.

Latency

There could be enormous latency in the network because of network blocking and multi hop routing.

Unattended Operation

When directing the functionality of specific WSNs, sensor nodes may be unattended for a long period of time [9].

Exposure to Physical Attacks

The WSNs Sensor nodes placed in open environment due to this that it is easily visible to the adversaries. The ratio of facing physical attacks in sensor networks is significant higher than typical computer systems [10].

Managed Remotely

WSNs are control remotely so that it is difficult to maintain and find out the physical intrusive in the network.

B. *Security Requirements*

The security requirements of all WSNs can be characterized as follows [11][12]:

Authentication

In process of communication or exchanging of switching information trustworthy authentication between sender and receiving sensor node is required.

Integrity

An unauthorized or an invader can be altered data during the transference process by the illegal access. Integrity in information guarantees that information is safe or not once transformed or alter during transference.

Data Confidentiality

Some applications need dependency on confidentiality. Some applications are key distribution, data surveillance system as well as industrial secrets. Encryption is a standard technique for assuring confidentiality.

Data freshness

In Security Requirements verifying the data must be fresh and not repeating the previous messages when mutual keys are recycled in WSNs. In this incident possible adversary can originate an attack with usage of old key [13].

Availability

There is a big issue of limited battery power. In huge communication therefore the Sensor nodes become absent. Unavailability of nodes can happen due to battery power expiration that an intruder may blocked the communication. The security requirements must assure the sensor node availability.

Self-Organization

In WSN, each sensor node is self-governing, random deployment and abundant to be self-healing affording to different disturbance environments, no fixed infrastructure, and support multi hop [7][9]. There is deficiency of an individual infrastructure in Wireless Sensor Networks because all sensor nodes in the Networks are self-governing and establish randomly as well as each node has the feature of self-curing due to numerous hassle environments. There is essential need of self-organized networks of nodes to keep up multi hop routing.

Time Synchronization

Some security method accessible to bring together the sensor nodes to make Wireless sensor Networks time-synchronized due to any node might be shut down to save power.

Secure Localization

WSNs repeatedly need information around the position of sensor nodes suitably as well as unavoidably. An attacker can basically switch the information of doubtful place with help of broadcasting false strong point of signals as well as replaying the indications etc.

Nonrepudiation

It illustrate that sensor node cannot discard to send the communication if the message directed before. Moreover we recommend the forward and backward secrecy.

- Forward secrecy: When a sensor node leaves the sensor network it cannot deliver any longer the upcoming messages.
- Backward secrecy: A fresh joined node may not be capable to deliver any of the previous communicated messages.

C. *Threat Model*

Ordinarily expected that an intruder might identify the procedures of security planned in WSNs or may be captured a sensor node actually. Due to organizing high charge sensing nodes. There may be few nodes seems to be compromised nodes, with the help of compromised node an invader with no trouble access the key resources.

Attacks in WSNs can be distributed into the following groups [14]:

- The attacks can occur from inside or outside the network. Outside side attacks takes from sensor nodes not from sensor network. While an authentic sensor node performed negative activities or break communication law taken as insider attack.

- In passive attack attacker scanned exposures and open ports of the sensor network without communication by catching the session ID or engage the sensor nodes by skimming its ports.
- However the active attacks contain some types of adjustments of data flow or construction of immoral data flow.
- In mote-class, an attacker attacks the wireless sensor network with the support of few nodes which have identical abilities to the sensor nodes.
- Laptop-class attacks, the intruders might have greatly powerful devices, which have too much control for processing, higher range for broadcasting as well as replacement a percentage of energy as equated to the nodes of WSNs.

D. Evaluation

Few metrics could be used to discover the appropriateness of security system inside sensor network [11]:

Security: A security technique should achieve the simple needs.

Resiliency: The security device should protect the attacks.

Energy Efficiency: Security device should also authenticate the energy effectiveness in order to exploit the lifespan of the wireless sensor network.

***Flexibility*:** Key management should be flexible in order to authorization multiple network organization methods like uninformed scattering of sensor node as well as commitment of arranged node.

Scalability: Security tool should adept to scale the security needs.

Fault-Tolerance: Security tool should adept smooth and accurate transmission for communication throughout the incidence of fault nodes.

Self-healing: The security device must be self-healing as nodes should be able to reposition in case of network failure.

Assurance: The arrangement of security must be capable to recommend varieties with respect to ideal reliability, latency etc. The security technique should fulfill the assurance of dividing information to different users [15].

E. Attacks in sensor networks

Attack can be identified signature based or anomaly based. In different work attack can be sensed in diverse techniques such as

- **Hello Flood**, wormhole attack occurs due to power strength difference of signal in WSN.
- In **DoS** attack attacker used garbage value that a sensor node accept false value.
- The **jamming** attack take place with delays inside the frequencies.
- In **tempering** attack an invader has physically accessed to any node in the WSNs to get information about security keys
- In **Spoofed, Replayed and Altered** attacks attacker straightforward targeted on routing protocol in WSN while swapping data between nodes.
- **In Selective Forwarding** an invader can create bogus nodes which only sending the choosy messages and drop others
- In **black hole** attack attacker drop all the data packets that sensor node expected.
- In **sinkhole attack**, an invader with the help of a fake node appearances attracting to all other neighboring nodes in order to get the routing information.
- In **Sybil attack** the invader used many identities in a sensor network.
- In **Wormholes** attack occur due to low-latency link in WSN.
- **Hello flood** a**ttacks used** HELLO packets to consume the energy of other sensor nodes by making artless supposition that the source node is the neighbor range.

II. Semantic based Wsn Architecture

Depending upon heterogeneity in System, Structure, Syntax and Semantics data Integration is a difficult task. OWL/RDF used to describe the sensor services. Sensor/Monitor Node used IEEE 1451 Standard for categorizing data and information link. Web service called using WSDL based on XML format. RDF describe relation in triples “Subject + Predicate + Object”. Ontology is a “*formal specification of a shared conceptualization*”. User gets web services using registry request type public or private using UDDI. SOAP protocol used for switching building information in web services. Jena API used to extract statistics from and create graph in RDF/OWL format, which queried through SPARQL.SWRL rules used for system behavior analysis is a normal or a malicious.

III. Approach used to Detect Attack in Wsn

A number of security procedures used to distinguish the information based, pattern based, and rule based, formal based and heuristic conceptions and combination of these technique attacks through IDPS. IDPS categorized into three types Application based, Host-IDS and Network-IDPS. due to knowledge base in Semantic Web attack divided into two categories (i) Detectable (ii) Undetectable. Non-ontological approach can only detect detectable attacks which is not efficient approach because signature of any attack can be easily modify. Ontology approach is stretchy to describe any perception at any level and can be used and shared between different individuals within domain. Ontology reduce large variation of sets into a list of properties.

IV. Related Work

In different research used different tools to detect attack such as DAML + OIL (DARPA Agent Markup Language), DAML Jess KB and for security assumption used UPML Unified Problem Solving Method Description language. In another work used (Descriptive Logic based Web Ontology Language) OWL-DL for attack detection due to expressiveness and full inference support. In [17] attack occur in Semantic web are XML, SQL, XPath Injection attacks, SOAP attacks, UDDI attacks. DoS attacks, XSS attacks, Application attacks.

In mostly research used layered approach to detect attack in WSN. In [1] used four layers and use Co-Operative Intrusion Detection Algorithm which based on number of different agents. In [16] used two layers and use Co-WIDP (Collaborative-based wireless IDPS) technique.

In [5] used Rough Set Theory and Sport Vector Machine to detect attack. In [6] used different IDS System to detect attack i.e. Target Centric Ontology, Outbound ID Architecture and semantic Ontology. In [18] used SUMO (**Suggested Upper Merged Ontology)** and IEEE 1451 Transducer used for Sensor Network which merged three ontology SHO (**Sensor Hierarchy Ontology),** SDO (**Sensor Data Ontology)** and EPO (**Extension Plug-ins Ontologies)**. In used Agent based Simulation Novel Approach used to detect DDOS in any critical Infrastructure with anticipation game which depend on four thing Dependency Graph (Network Services, a set of attributes (States) , rules, policies and Communications proceeds between the attacker and the protector.

V. Proposed Architecture

F. *Overview of the planned model*

IDPS classified such as

- Application based IDS detect intrusion in a particular application protocol.
- Host-IDS has single node user log info etc.
- Network-IDPS has info about flows, data packet and protocol activities in specific network section.

Attack can be discovered signature based or anomaly based.
In some previous research work used Fuzzy reinforcement Learning Management, security ontology, Knowledge management and multi Agents System to monitor, analyze and collect audit data through sensor Node and detect intrusion through complex technique. However if number of agents is more than maximum delay occur.
In our proposed architecture we expand the security ontology design by covering the relation sets concluded properties and distinguish diverse attack sort such as **active or a passive** attack and associate attack type. Also reduce their attack exposure time and create the semantic based WSN-IDPS Architecture. The proposed architecture is arranged into three parts.

1. Agent System and Security ontology.
2. SWRL Rules.
3. Ontology workflow.

This presents the anticipated design of WSN to detect attack. In our system at section 1 configured WSN routing information and WSN attack packages/sets, section 3 agent system consist two agent common agent and monitor agent. Common agent collects data from section 2 and patterned its status Section 3. Section 4 match malicious activity pass this report to monitor agent which inquiry to security ontology and decide the actions of data, useful data than permit it to go the prerequisite Sensor Node or else decided about the attack signature, section 5 develop IDS and update the section 1 and generate alert system to user. Fig. 1 presents the proposed architecture,

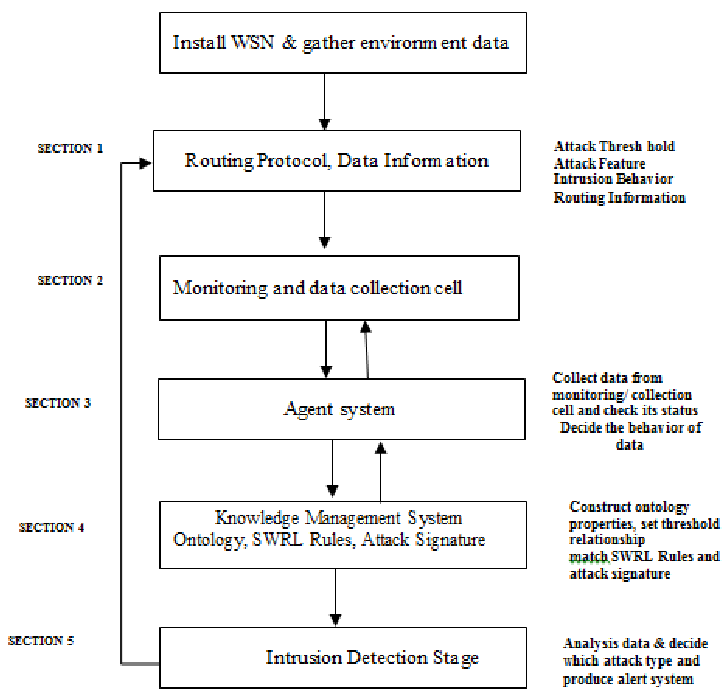

Fig. 1. Proposed Architecture

To develop agent system used Jade, Java Agent Development Framework. To create relations between Agents and security ontology used Jena, Java framework for constructing WSN Architecture, to create graph in RDF/OWL format, which queried through SPARQL.

VI. Proposed SeCurity Ontology

After in depth analysis of Wireless Sensor Network domain, we conclude that the web Semantic based WSN ontology is the appropriate to identify the diverse WSN attack.

Attack ontology can be built by studying special domain or reused/rebuild previous ontology accessible in that domain to complete. Intrusion Detection System has insufficient ontologies. Attacks can be classified into two groups: active and passive attack**s.**

a) Active Attacks

In Active attack groups attacks are Acknowledgment Spoofing. Black Hole, Message corruption, physical attack, sniffing attack , in routing attack hello flood , selective forwarding, sinkhole , Sybil attack wormhole, Node attack, and in DoS hello flood, energy drain. Network congestion, jammers.

We build our recommended ontology by using open source Protégé. Fig. 2 shows the upper level classes of Active Attacks, data individuals and sensor nodes individuals.

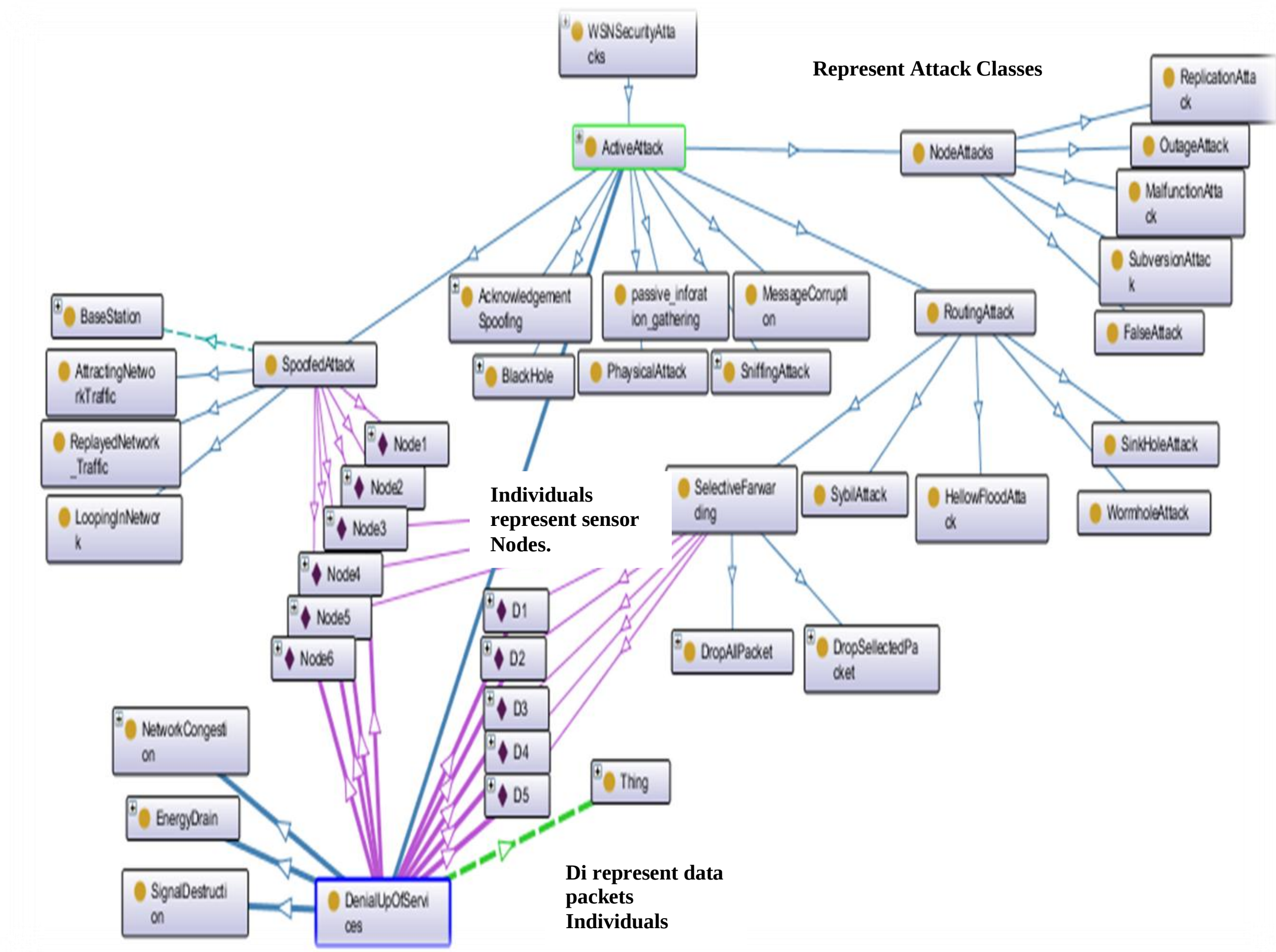

Fig. 2. Active Attack

b) Passive Attack

In passive attack invader scanned vulnerabilities and open ports of the system without interaction by capturing the session ID or engage the system by scanning its ports. Invader used war driving, antenna and GPS system and dumpster diving method used to attempt such type of the attack. The main purpose of this attack is to get information around the target like traffic analysis and no data is altered. Passive attacks are preliminary actions for doing active attacks. Figure 2 shows the upper level classes of passive Attacks. Passive attack IDS beyond our work.

Passive attacks are traffic analysis, Monitor and eavesdropping, MAC Protocol and camouflage adversary.

VII. Intrusion Detection Algorithm

In our scenario used six Sensor Nodes $_{(I)}$ and assign each node an ID for authentication and session ID for communication. First we set the **threshold Value** to detect different type of attack in ontology.

A. Symbol used for proposed Algorithm

Sensor Nodes NID [ ], Monitor Node MID [ ], Energy Status E-fi, for Radio Communication Range used RCR and sensed data kind info SDT, resources of sensor Node used RSN [ ] , for communication session information such as starting time, data transmission time and communication completion time store in time[ ] and for isolation table used IT[ ].

B. Intrusion Detection Stage

The intruder that intrude wireless sensor network into two phases:

- Initial attack phase about attack behavior
- Destruction phase about attack type.

The intruder used various programing ability to burn comprehensive network, even marks WSN unfeasible. These activities are called anomaly acts. The ontology covers the comprehensive relationship of the WSN. The common nodes transport section of ontology and Monitor Node contest the SWRL rules to detect different sorts of attacks.

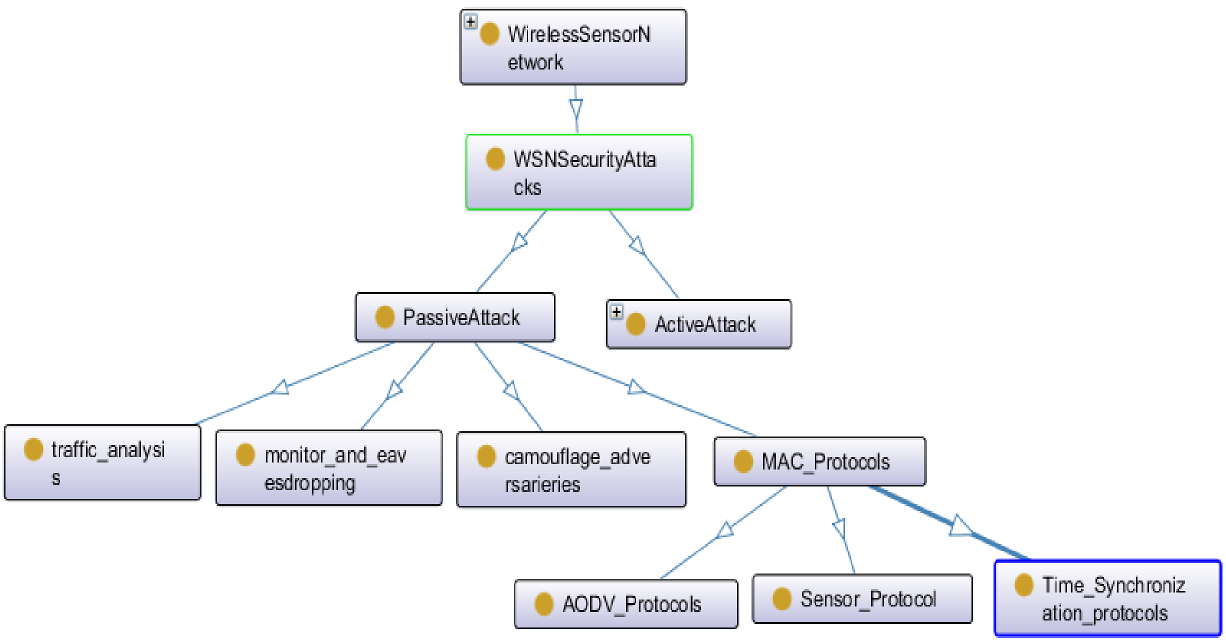

Fig. 3. Passive Attack

C. Algorithm to detect different attacks in WSN

Input: The WSN communication packages and attack packages

Output: MID list of Malicious Nodes MID[]

- Pre-processing and broadcasting routing Stage

for each Sensor Node SN attached to N do
/*where N represent a particular WSN Segment*/
for each sensor node S_j in the network do
if $D_{SN}[S_j] + S_{ID}(N, s_i) < D_N[S_j]$ then /*here D represent distance information of a sensor Node*/
/∗a better route from N to S_j through SN has been found∗/
$D_N[S_j] \leftarrow D_{SN}[S_j] + S_{ID}(N, s_i)$.
$CH_N[S_j] \leftarrow (N, SN)$
/* CH represent the cluster head of a network segment*/
for each Sensor-Node SN transmitted to Base-station BS do
Send data of itself S_{ID} to base station BS
return S_{ID} /* Info about Sensor Node ID*/

- Concept to build Ontology Stage

/∗ sort sensor nodes in respect to energy status ∗/
for each sensor node SN in the network do
for ($i = n - 1$; $i > 0$; $i - -$) do
for ($j = 0$; $j < i$; j++) do
if energy(SN_j) > energy(SN_i) then
/*NID represent Sensor Node in network*/
buffer = NID[j]
NID[j] = NID[$j + 1$]
NID[$j + 1$] = buffer
return NID[]
/∗ return sort information of active Node in WSN ∗/
/∗ this arrangement selects best sensor node as a Cluster Head in particular Network Segment and in NID[ ] array at index “0” Sensor Node has highest energy status ∗/
set CH = NID[0]
/∗pick up next two Sensor Node as a Monitor nodes∗/

for (m =1; m< n ; m++) do
/*here the value of n is less than "3" */
MID[m] = NID[m]
/∗ pick up two sensor nodes as a monitor node which are at index 1 and 2∗/
for each sensor node S_{ID} in the MID[] do
if hop(SN_i, CH) = 1 then
/∗a Monitor node has found∗/
set MID[] = SN_i

- Construct Monitor nodes in Ontology

for each Monitor node in the network do
for (m =1; m< n ; m++) do
/∗ m is the index of Monitor node ∗/
/∗ $MN_i \cap MN_j$ compare the data of MN and MN_j to collect the lowest number of source such as energy-status ( ), hop ( ) and sense-data-type ( ) etc. MN_i U MN_j calculate the data of MN_i with the statistics of MN_j to collect the smallest number ∗/
t_m = intersection (MN_i, MN_j) / union (MN_i, MN_j)
$MN_j[] \leftarrow MN_i$
Ontology[] ⟵ MN_j[]

- Relationship b/w Sensor Nodes

for each Sensor-Node SN_{ID} in the network do
if SN_i <> SN_j and resource(SN_i) $\neq$ resource(SNj) and hop(SN_i, SNj) = 1 then
/* SN_i , SN_j are two differ Node, resources are different and distance b/w them is same from one hop and MN_i managed these sensor nodes*/
/∗ an equivalent sensor Node has initiate ∗/
set SN_i , SN_j are equivalent sensor nodes
for each Sensor-Node SN_{ID} in the network do
if SN_i <> SN_j and resource(SN_i) ≈ resource(SN_j) and 2 ≦ hop(SN_i, SNj) ≦ 3 then
/* SN_i , SN_j are two differ Node , resource are same and distance b/w them is "2" then differ Monitor node are on same level and have sister co-relation or less than and equivalent to "3" from one hop then have sibling co-relation and it will be adjusted conditionally on the scale of WSN */
/∗a sibling sensor Node has found∗/
set SN_i and SNj are sibling Sensor Nodes
else if Monitor-Node(SN_i) ∩ Monitor-Node(SNj) <> then
set SN_i and SN_j are sibling sensor nodes.

- Construct Ontology

for every SN in the network do
for (i = 1; i≤ n; i++) do /∗ i is the index of Monitor Node ∗/
ti = intersection (MN_k, SN_i) / union (MN_k, SN_i) /∗t_i is sister co-relation of Monitor Node i ∗/
$t = t + t_I$ /∗t indicate the sister or Sibling term ∗/
return t
Monitor-Node (MN_k, SN_i) = t/i
$MN_i[] \leftarrow SN_i$
Ontology[] ⟵ MN_i[]

- Intrusion Detection Phase for physical Node, false Node, Node Malfunction, Sink hole, Sybil attack, Hello flooding and black hole attack

for each neighbor Sensor Node of Monitor Node **do**
receive (SN_{ID}, MN_{ID}, SN_{INFO}, E_fi)
/∗ Receive SN_{ID}, MN_{ID}, SN_{INFO} and the remaining energy ∗/
if S_{ID} <> *Ontology* [] then
/∗ Checked whether the sensor node is built in the Ontology ∗/
then AN[] = (SN_{ID}, MN_{ID}, AN)
/∗ Record SN_{ID}, MN_{ID} and anomaly information ∗/
if Pattern (SN_i) ! = Pattern (AN)
/∗ Check whether the receive information is different from attack knowledge ∗/
then AN[] = (SN_{ID}, MN_{ID}, AN)

/∗ Record SN_{ID}, MN_{ID} and anomaly information ∗/

else if broadcast AN[] to CH /∗ Broadcast isolation table to CH and update anomaly and signature database information for back up ∗/
end for

- Wormhole, Acknowledgement Spoofing attack, black hole, Message corruption, sniffing attack, signal destruction/jammers and Routing attack detection phase

This **wormhole** attack can be detected by data packets are saved in Monitor Node buffer when sender and receiver Node exchange data packets with each other and also keep record of time threshold of each data packet to verify the correct information of Monitor Node. Check information status in buffer. AN[i] maintained of each Monitor $Node_{id}$ and keep record of each Monitor Node sliding window MN_{S_Window} . Monitor Node keep record of its nearest sensor node. Monitor Node explored logical position of sensor node. However in WSN adjacent node may be alteration their position during lifetime of network. So dynamic detection required. Malicious Node easily detected because each sensor node record exist in ontology. When a sensor node receives the request channeled by a malicious node it append the identity of malicious node or its neighbor node. It can also be detected due to it has no packet information of SN_j in its buffer.

/* Authentication process b/w $Node_i$ and $Node_j$ */

for each Sensor Node SN attached to N do

/*where N represent a particular WSN Segment*/

/* Radio Communication Range used RCR, resources of sensor Node used RSN [], for communication session information such as starting time, data transmission time and communication completion time store in time[ ] and for isolation table used IT[ ].*/

1) for each sensor node SN_j send message MN_i with the time[] to SN_j which expects with RCR, to in the network do.

2) MN_i encrypt SN_i request using public symmetric key.

3) MN_i check its Routing Table for SN_i to verify SN_i has no previous valid communication session. And SN_j has not already revoked. If SN_j has already authenticated then

Monitor Node drops the handshaking request by private key sending back to SN_i.

4) If step 3 do false, Monitor Node send Acknowledgement that contain the id of $SN_{i,}$ session expiration time[i] , this time equal to the Monitor Node handshaking request time for authentication and new location information of Node SN_j and send back to SN_i.

5) When SN_j receive the result of authentication process than SN_j acknowledgement through public key to Monitor Node.

6) If Monitor Node reject the SN_j request, then every Sensor Node in this network segment reject the communication request of SN_j and add his path address to isolation table IT[].

7) If position remained same in Authentication process and communication time is not expired than a Sensor Node can send, forward and receive data packets.

8) If current position is changed from authentication process and time limit expire than a Sensor Node cannot send, forward and receive data packets.

9) SN_j send broadcast hop for its authentication, than authentication process determine its neighbor Sensor Nodes

10) Neighbor SN_i accept the detection of authentication and proof the initials of Monitor Node and its future communication session, again collect the clock synchronized time information and compute hop distance of SN_j and add it as its neighbor Node list along his current position and store SN_j position.

11) SN_i directs its own authentication using shared key to SN_j along its local malicious Node list MN[] .

12) SN_j verified the authentication of SN_i using the initials of Monitor Node and its communication session time and update its neighbor sensor node list and computed distance of SN_i and its own location and store the malicious node list of SN_i

13) When SN_j complete or expired its communication process than SN_i remove SN_j to its neighbor Sensor node list.

VIII. Results and Evaluation

The results detect main assessment criteria, the particulars of data set, the attack structure; system specification and final results of the research approved complete the system.

- System Specification
- Core i5

• System Processor	• Intel® Core (TM) i5 4010U CPU @ 2.70 GHz
• RAM	• 4GB
• HDD	• 500GB
• Operating System	• 64 bit Windows 8.1
• Tool	• Protégé, Java

Sensor Node Concept in Ontology

The ontology data consist of sensor node ID, Monitor node ID, energy in joule, hop distance and sensing data type i.e. temperature, humidity, Brightness.

TABLE I. NODE STATUS

Node Type	Energy level in joule	Hop
Cluster Head	Top most energy	1
Monitor Node	89% to 80%	2 to 3
Sensor Node	below 80% to 30%	4 to above
Dead Node	below to 30%	---
Attacker Node	Use Threshold value	

Implementation environment

- Sensor nodes 10
- Monitor nodes (20% of SN) 02
- WSN size $1000 * 1000m^2$
- Starting energy 2 joule
- Transmission radius 100m
- Transmission consumption 0.072w
- Receive consumption 0.048w

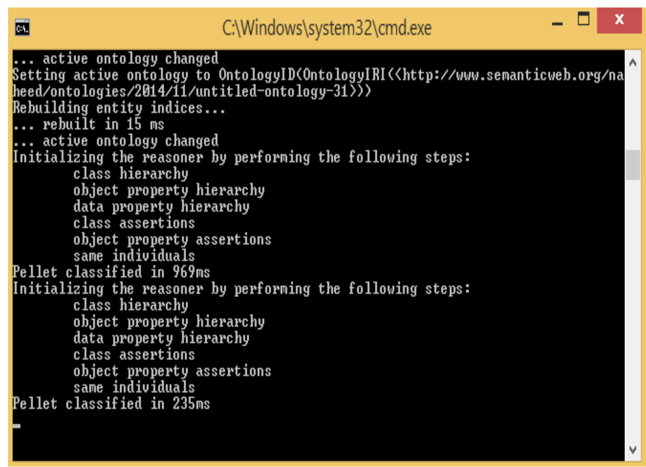

Fig. 4. Pallet inferences

Security Ontology Metrics and class axioms include 66 classes with constrained time inference. Pellet conclusion engine categorized between class, object, data property hierarchy, class assertion, same individuals in 969ms 1st time and 2nd time classified near about 235ms shown in figure 3.

The total time of Simulation was 1800 sec on prowler simulator. Attacks were unsystematically performed every 15 sec with attacks start at 300 sec. To assess the presentation of the system, succeeding formulas and technique are recycled to measure system accuracy:

- Number of Normal communication Records: NCR
- Number of Attack Records during transmission: NAR
- False Positive Attack (mean attack detection signature based): FPA

- False Negative Attack (Mean attack detection Anomaly profile based): FNA
- Detection Rate Percentage = [(NAR-FNA)/NCR]*100
- False Alarm Rate Percentage = [FPA/NCR]*100

IX. Conclusion and Future Directions

We have given a detailed analysis of results and upcoming directions where the proposed work can be used. A foremost conclusion is that the outcome of ontology can be surveyed in the wireless sensor network attack detection. The results show that the ontologies can be used in Wireless Sensor Networks to detect attacks successfully. This indicates that an ontology specifying each role and its individuals in the Wireless Sensor Network could be developed for different attack types.

This work leads to an ontology based ID-System which agree to us to study the relationship method concerning Monitor Node status and Common nodes. More than one ontology is used to reduce or detect attacks in ID-Systems in wireless sensor networks. Overall, they will be suitable in refining the lifecycle of WSNs and, mainly usability to detect different attacks for wireless sensor networks. Contributions of the research involve involvement of the suggested methodology for semantic interoperability throughout the process of communication in WSN. The correct assessments of the system tested through Algorithm of the Semantic base Intrusion detection System for Wireless Sensor Network. The passive attacks security concern will be resolved in the future work.

References

[1] A Semantic-based Intrusion Detection Framework for Wireless Sensor Network Published in Networked Computing (INC), 2010 6th International Conference by Yuxin Mao.

[2] H. Chan and A. Perrig, "Designing Secure Sensor Networks," Wireless Commun. Mag., p. 103–105, 2003.

[3] E. Shi and A. Perrig, "Designing Secure Sensor Networks," Wireless Commun. Mag., vol. 11, no. 06, p. 38–43, 2004.

[4] S. Naeimi, H. Ghafghazi, C.-O. Chow and H. Ishii, "A Survey on the Taxonomy of Cluster-Based Routing Protocols for Homogeneous Wireless Sensor Networks," Sensors, vol. 12, 2012.

[5] Ranger Intrusion Detection System for Wireless Sensor Networks with Sybil Attack Based on ontology new aspects of applied informatics, biomedical electronics & informatics and communications.

[6] Ontology-based Distributed Intrusion Detection System Abdoli,F.;Kahani,M. Publication Year: 2009 Proceedings of the 14th International CSI Computer Conference (CSICC'09)

[7] A. Jain, S. Deepak, G. Mohit and V. A. K., "Protocols for Network and Data Link Layer in WSNs: A Review and Open Issues," Advances in Networks and Communications, Communications in Computer and Information Science, vol. 132, pp. 546-555, 2011.

[8] T. Naeem and K.-K. Loo, "Common Security Issues and Challenges in Wireless Sensor Networks and IEEE 802.11 Wireless Mesh Networks," International Journal of Digital Content Technology and its Applications, vol. 03, no. 01, pp. 89-90, 2009.

[9] J. P. Walters, Z. Liang, W. Shi and V. Chaudhary, "Wireless Sensor Network Security: A Survey," Security in Distributed, Grid and Pervasive Computing Yang Xiao, vol. 10, no. 15, pp. 3-5, 2006.

[10] A. Pathan, H.-W. Lee and C. S. Hong, "Security in wireless sensor networks: issues and challenges," in The 8th International Conference on Advanced Communication Technology (ICACT), Phoenix Park, 2006.

[11] G. Bianchi, "A comparative study of the various security approaches used in wireless sensor networks," International journal of advanced science and technology," International journal of advanced science and technology, vol. 17, no. 01, pp. 31-44, 2010.

[12] T. A. Zia, "A Security Framework for Wireless Sensor Networks," 2008. [Online]. Available: http://ses.library.usyd.edu.au/ bitstream/2123/2258/4/02whole.pdf. [Accessed 10 December 2014].

[13] Y. C. Hu, A. Perrig and D. B. Johnson, "Packet leashes: A defense against wormhole attacks in wireless networks," in 22nd Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM '03), San Francisco, CA, 2003.

[14] J. Deng, R. Han and S. Mishra, "Enhancing Base Station Security in Wireless Sensor Networks," Department of Computer Science, University of Colorado, Tech. Report, Colorado, 2003..

[15] B. Deb, S. Bhatnagar and B. Nath, "Information Assurance in Sensor Networks," in 2nd ACM Int'l. Conf. Wireless Sensor Networks and Applications (WSNA '03), San Diego, California, 2003.

[16] An appraisal and design of a multi-agent system based cooperative wireless intrusion detection computational intelligence technique by Shahab shamshirband Publication Year: 2013

[17] Security Solution for Semantic SCADA Optimized by ECC Mixed Coordinates 2012 International Conference on Information Technology and e-Services by Sahli Nabil, BenMohammed Mohamed.

[18] A Universal Ontology for sensor networks Data by Mohamad Eid, Ramiro Liscano , Abdulmotaleb Ei Saddik Publication Year: 2007

Secure Steganography for Digital Images

Meandering in the Dark

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***Abstract*—The degree of imperceptibility of hidden image in the 'Digital Image Steganography' is mostly defined in relation to the limitation of Human Visual System (HVS), its chances of detection using statistical methods and its capacity to hide maximum information inside its body. Whereas, a tradeoff does exist between data hiding capacity of the cover image and robustness of underlying information hiding scheme. This paper is an exertion to underline the technique to embed information inside the cover at Stego key dependent locations, which are hard to detect, to achieve optimal security. Hence, it is secure under worst case scenario where Wendy is in possession of the original image (cover) agreed upon by Alice and Bob for their secret communication. Reliability of our proposed solution can be appreciated by observing the differences between cover, preprocessed cover and Stego object. Proposed scheme is equally good for color as well as gray scaled images. Another interesting aspect of this research is that it implicitly presents fusion of cover and information to be hidden in it while taking care of passive attacks on it.**

***Keywords*—Steganography; Imperceptibility; Information Hiding; LSB Technique; Secure Communication; Information Security**

I. Introduction

The word Steganography is derived from Greek means "Hidden Writing" [1] and dates back to 440 B.C. [2]. Some earlier examples as reported in [3] include: shaving scalp of a most trusted slave to etch a secret message and waiting for the hair to grow after which he was sent to allies who retrieves it by reshaving his head; engraving messages on wooden Tablet and then covering it wax. The receiver retrieves it by melting the coated wax. A comprehensive insight on unconventional steganographic schemes has well been elucidated in [4].

Steganography is an ancient art [5] that with technological revolution has now been evolved into a science [6] to avert detection of hidden data. [7] delivered terminology for steganography while Simmon [8] gave the first model for steganography by discussing the scenario of Alice and Bob held in separate prison cells had to communicate through Warden Wendy. Types of steganographic system are discussed in [9] as pure (with no Stego key), private key and public key respectively whereas three techniques for steganography including insertion, substitution and cover generation have been discussed in [10].

Cryptography, having Greek origin and with same inception period as that of steganography, means "Secret Writing" [11] the essence of which is to inarticulate secret information in contrast to steganography whose sole perseverance is to conceal the fact that such information does really exist. Though opposite to each other in their approach, these two serves well as a double edged weapon to safeguard information security frontiers [12-14].

The mammoth growth of internet as communication medium has insentiently provided an opening for surreptitious communication that has been exploited in full by academics and mavens through variety of file formats (as hidden information carrier) that exist for text, image, audio and video etc. storage and representation. This paper besides presenting an innovative secure scheme for LSB based image steganography, also expounds on predominant misconception regarding detection and that for favoring bulk of online data exchange. The paper is planned as follows:

Section II introduces reader with basics of image steganography. Following this, in Section III, is the literature review of some the most recently published research articles on LSB based steganographic schemes. Theoretical foundation to disregard misapprehension of detection of steganography is the prima facie of Section IV. Section V elaborates on the proposed secure data hiding scheme while Section VI presents test results. Misapprehension about cover's capacity is discussed in Section VII. Technical analysis of the proposed logic is given in Section VIII. Advantages of the proposed scheme are highlighted in Section IX. Future work comes in Section X and Section XI concludes the discussion.

II. Brass Tacks

An image can be thought as a logical arrangement of color(s) perceived by human as an object. A digital image on the other hand is viewed as a two dimensional function $\boldsymbol{i}(x, y)$, where x and y are plane coordinators pointing to a unique value, corresponding to light's intensity [15] at that point, and stored as raw data inside persistent storage which gets its meaning from the header that precede and relates it to a specific file format e.g., BMP, JPEG, TIF etc.

Image can be stored as black and white, 8-bit (mishmash of black and white colors) as shown in Fig. 1 in the form of 8 x 32 matrix, 16-bit or 24-bit files. A 24-bit color image is expressed in terms of multiple groups of 3-bytes each analogous to red, green and blue colors called RGB colors that tally to $2 \wedge 24 - 1$ colors in total, but 8-bit images for steganographic purposes are more suitable because it offers steady transformation of shades (from 0 ~ 255). 16-bit images have varied RGB representations such as 5 (R), 6 (G), 5 (B) / 5, 5, 5 (excluding LSB) bits etc. [16-17].

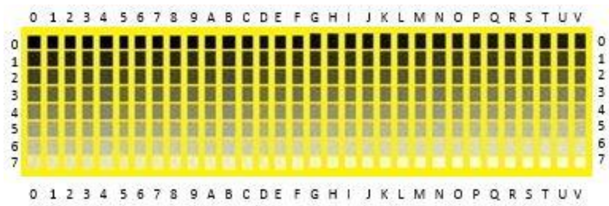

Fig. 1. 256 Shades of a Gray Scaled Image

Lossy and lossless data compression techniques are / can also be applied on images e.g. JPG etc. [18]. The former, however, may result in loss of valuable hidden information.

A. Classifying Image Steganography

Image Steganography is characterized in [19] as Spatial Domain (Plane co-ordinate system), and Transform (Frequency) Domain where former permits direct bit manipulation while for later a digital image is first transformed and then manipulated [20].

a) Spatial Domain data hiding algorithms are discussed in [21] that includes:

1) Non-filtering Algorithms – LSB replacement. Pixel Value Difference (PVD) is also being discussed for spatial domain steganography such as in [22].

2) Randomized Algorithms – Over comes drawback of sequential placement of LSB bits.

3) Filtering Algorithms – Separates Most Significant Bits (MSB) from LSB for using less significant bits for information hiding.

b) Transform Domain data hiding schemes are:

1) Discrete Cosine Transformation is the focus of research in [23-24].

2) Discrete Wavelet Transformation, for which [25] be seen

Because conversion from one domain to another is without any loss of information, hence some techniques such as follows, works well in both domains.

1) Patch Work discussed in [26-27].

2) Spread Spectrum shown in [28].

B. Attacks on Steganographic Systems

Cachin in [29] expanded on two types of errors that Wendy may commit towards detecting hidden information exchanged by Alice and Bob as follows:

a) *Type – I (False Positive) Error: Wendy detects a hidden message inside the cover where no message is sent.*

b) *Type – II (False Negative) Error: Wendy clears and let go a cover that does carry a hidden message.*

Based on above analogy any steganographic system is ought to be evolved to maximize the probability of occurrence of Type – II error.

Active and passive types of attacks are discussed in [30] where former intentionally attempts to remove hidden information whereas the later tries to extract the hidden information for analysis/retrieving hidden information from the Stego object.

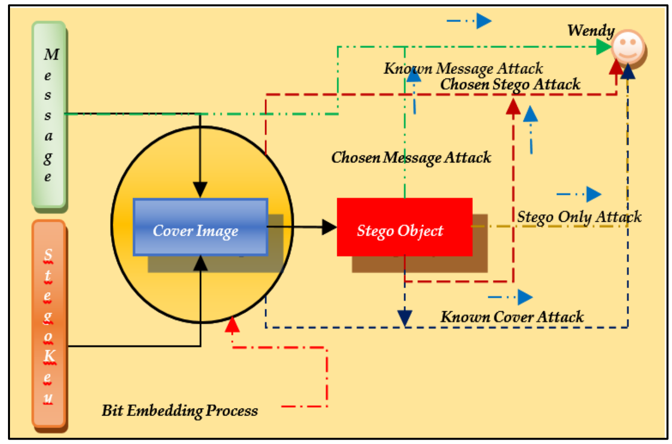

Fig. 2. Five Types of Attack on Steganographic System

[31] has categorized attacks on any steganographic system into five types depicted in Fig. 2 with a concise explanation of each as follows:

1) Chosen Message attack. Here the attacker aims to unfold the effect of embedding algorithm by choosing messages of his/her choice.

2) Chosen Stego attack. With selected Stego objects, the attacker tries to arrive at the embedding algorithm.

3) Known Cover attack. With known cover and its corresponding Stego object, an attacker attempts to contrast differences in the two to conclude on hidden information.

4) Known Message attack. Here an attacker tries to unfold the information embedding methodology by analyzing the Stego object.

5) Stego Only attack. The attacker is in possession of Stego object and tries to extract hidden information out of it.

In order for secure steganography to prevail, it is desirous that any steganographic scheme must take into account all types of attacks.

III. Literature Review

A. LSB Steganography for Digital Images

As evident from Fig. 3 that shows 8-bit gray scale image when split into corresponding eight bit planes (from low order bits to high, in sequence) - lower order bits carry subtle (visual) details about an image in contrast to high order bits. Hence, changes made in the least order bits can seldom have an impact on image appearance in general but only when analyzed in milieu of limitation of Human Visual System (HVS) [32].

Least Significant Bit Steganographic technique (for digital images) substitutes secret bit of information at least significant position of every pixel of an image i.e., 7^{th} from left to right with most significant bit at 1^{st} position. [33-39] presented the rudimentary manner in which LSB technique works (for further study on its progression [40-41] serves as reference) which, since then, has been experimented on varied levels of LSB positions [42-43].

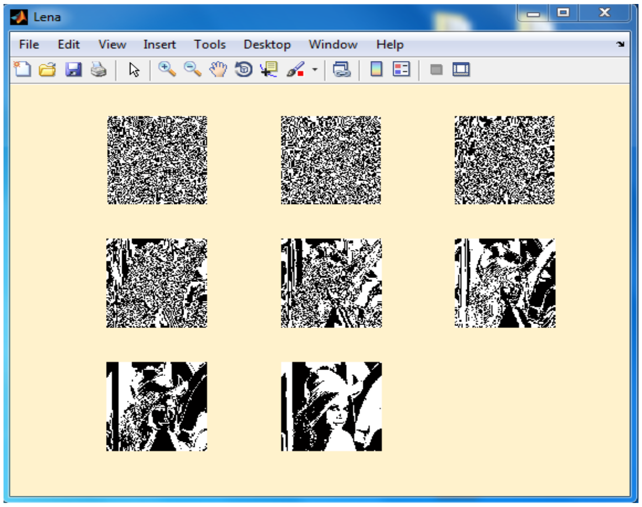

Fig. 3. Eight-bit plane slice view of an Image

Basic LSB substitution technique works as follows:

Let the following represent various shades of gray level:

"11110010 01011010 10010001 10110100 01010101 01010110 01100111 01001101" of cover image, and let letter "F" having binary "01000110"be the secret message for hiding purpose. Substituting/replacing the LSBs of the cover gives following new gray level pixel bits: "1111001<u>0</u> 0101101<u>1</u> 1001000<u>0</u> 1011010<u>0</u> 0101010<u>0</u> 0101011<u>1</u> 0110011<u>1</u> 0100110<u>0</u>". In terms of intensity, the cover image and the resultant Stego (image) object has following values:

Cover Image: 242, 90, 145, 180, 85, 86, 103, and 77

Stego Object: 242, 91, 144, 180, 84, 87, 103, and 76

, with a negligible difference of 0, 1, 1, 0, 1, 1, 0 and 1 respectively, and is imperceptible to human eye.

An aberration associated with application of LSB technique for every byte of 24-bit color (R, G, and B colors), however, is elucidated as follows:

Let "11110010 01011010 10010001" represent the 24-bit RGB representation of a particular pixel of cover image. If "010" is the secret message then after its substitution at LSB positions in RGB composition, the Stego object has the bit combination "1111001<u>0</u> 0101101<u>1</u> 1001000<u>0</u>". In terms of intensity, the cover image and the resultant Stego (image) object has following values, with a noticeable difference of 255.

Cover Image: 15882897

Stego Object: 15883152

[43] epitomized LSB substitution using secret key for bit embedding and extraction. It is, however, opined that the illustration does not have taken into account the *known cover attack* without which the appraised scheme isn't may not be regarded as secure.

[44] improvised Matching LSB scheme that according to its author has lowered probable number of alterations per pixel to 0.375 rather than 0.5. [45] offered a more generalized way of LSB matching that further reduced the aforesaid probability of altered pixels.

Pixel value difference scheme was proposed by [46] that exploits the difference of two adjacent pixels for data hiding purpose.

A noticeable outcome of research on LSB steganography [47-49] showed that histogram for simple LSB substitution appears as "pair-wise" that can be easily identified by Chi-square test.

Adaptive LSB scheme based on piecewise mapping function relating to HVS masking physiognomies is proposed by [50] while research work conducted by [51] is based the on contrast and luminance properties of HVS.

Existing LSB based/amalgamated schemes are continuously being evolved such as [52-57] etc.

B. *Steganalysis*

Analogous to cryptanalysis, steganalysis is the art and science of *detecting* hidden information inside a cover without the knowledge of the embedding algorithm and the key [58]. However, it is to be noted that here the word 'detection' be taken purely in context of distinguishing *actual hidden contents from any induced artifact* because of the chance of 'error' associated with steganalysis methods as shown in [59] for images that are devoid of entrenching.

Over the years a number of steganalysis methods such as [60], [61], [62], [63], [64], [65] and [66] have been proposed to counter digital steganographic schemes. Pair of Values (PoVs) are statistically analyzed by [67] that works well for contents when hidden sequentially. [68] recommended dynamic compression after LSB steganography that minimized payload detection inside cover image. [69] called for matrix embedding for increased security of steganographic schemes. [70] suggested 'flipping' of cover image in a manner that randomly transforms 50% LSB's of all pixels resulting in false estimation of cover either with or without hidden data that remained unchanged after bit embedding. Although proposed analogy as stated by its authors, is successful against accurate steganalysis methods such as RS [71], Sample Pair Analysis (SPA) [52], and Least Square Analysis (LSA) [59], the limitation of the said scheme is that estimation error tends to zero for 100% payload. It is, however, orated in context of Section 2.2 that other associated limitations of the said scheme include:

- Cover image used once must never be reused
- What is referred as random flipping (transformation) of LSBs' by the authors, in fact, seems as a linear one, and
- Scheme's non adherence to Kerckhoff's principle

IV. THEORETICAL FACET

A. *Statement of Purpose*

Before discussing security, an important aspect is to apprehend the difference between secrecy and security. Secrecy is concerned with confidentiality within certain bounds while the latter is the extent up to which attacks may be withstand against any system. For discussion on the limitations of perfect security for steganographic systems [72] is referred.

According to [2], "in a 'perfect' system, a normal cover should not be distinguishable from a Stego object, neither by a human nor by a computer looking for statistical patterns." Going strictly with it, however, reveals that no matter how sophisticated and complex the information hiding scheme may be, none of the techniques may withstand foresaid scenario and known cover attack where the hidden information can easily be *detected* and extracted by contrasting it with the Stego object i.e., the security of the system lies in keeping 'original cover' *secret*.

So what to strive for to have a secure steganographic system? Interestingly, the foresaid limitation of prevalent steganographic techniques/schemes also explicate on *evolution of data hiding scheme that does not necessitate the need to keep original cover secret* such that comparison of cover and Stego object does not hint at actual hidden contents while still being in compliance with Kerckhoff's principle. This also serves as the *statement of purpose* for the proposed research.

B. Modus Operandi

Following expounds on the core concepts, and preliminaries for the proposed model for data hiding:

1) Exploring candidate pixel values for data hiding in an 8-bit image: In order for the proposed bit embedding methodology to work effectively the researchers experimented with 100 8-bit gray scaled images of varying shades acquired from [73] by altering their 1 or 2 LSBs. Research findings indicated that LSB substitution worked well for the luminance in the range 0 through 63, range 64 to 95 may be engaged to accommodate more message bits if deemed necessary i.e., exceptional situations. Range 96 to 255, however, leads to statistical and visual discernibility of hidden data. Fig. 4 illustrates the research findings.

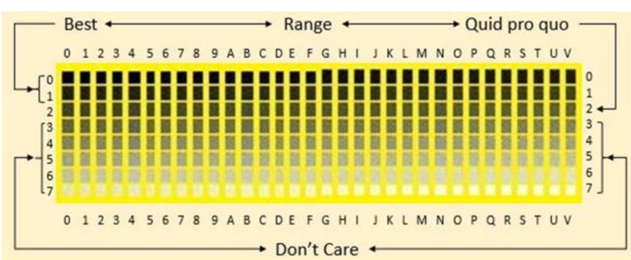

Fig. 4. Illustrating Acceptable Range of Pixel Values for LSB Secure Steganography

2) Avoiding Saturation and Wrap Around Situation

Image addition either with another image of similar dimension or a fixed value is more like an intermediary step rather than a complete process in eternity. Data retention capacity of 2-bits ranges from 0 to 3 corresponding to bit patterns {"00", "01", "10", "11"}. Since the intensity of an 8–bit grayscale image varies from 0 to 255, adding a constant value of 3 to each pixel may then results in a situation where the pixel intensity exceeds 255. Two possible scenarios for handling the overflow referred as *saturation* and *wrap around* exist respectively with their situational based (in context of choice of image) limitations which are graphically illustrated in Fig. 5.

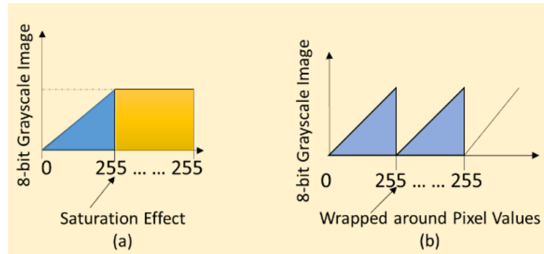

Fig. 5. Saturation and Wrapping around situations

Reducing higher values ≥ 256 to 255 as shown in Fig. 5(a) is constraint with increased illumination whereas wrapping around those values (i.e., $P_{x,y}$ MOD $256, x = 0,1,2,\ldots, N; y = 0,1,2,\ldots, M$) as illustrated in Fig. 5 (b) tends towards image darkening. To avoid saturation and wrap around situation the researchers assent on drifting the offset of an image but only for pixels having intensity ≤ 63 leaving rest of the pixels unchanged. This is so because binary equivalent of 63 is "0 0 1 1 1 1 1 1" and changing one/two LSBs shall always result in a pixel value ≤ 63.

In secret message bit embedding either for single or 2-bit pair (*obtained vide Stego key dependent processing explained subsequently*), the same shall be substituted in target pixel at LSB position(s) accordingly.

3) Message Header:

To ensure secrecy and reliability of hidden information referred to as 'C' (confidentiality) and 'I' (integrity) traits of information security, it was preferred to use Stego key dependent random substitution of one or two LSBs of cover image with encrypted header and message bits {using XoR Encryption i.e., (Header + message) XoR Stego Key} where the header comprises of secret message's length, its computed HASH (using SHA-256 [74] - digitally signed using RSA [75]), and file type i.e., file's extension. For XoR encryption, if the collective message bits exceed Stego key bits, HASH of the later gets recomputed (by treating previously calculated HASH as new Stego Key) and the continuing with the process. Table 1 reflects on the composition of message header.

TABLE I. MESSAGE HEADER WITH HIDDEN ENCRYPTED DATA

--- 32 bits ---	--- 32 bits ---	---- 32 bits ----	---(8 x N) bits---
Length of Secret File	Secret File's Extension	*Digital Signature* HASH	**Data**

4) Stego Key: 256-bit (32 Bytes) Stego Key (must be random).

5) Pseudo Random Number Generator: Details are beyond the scope of this submission.

6) Model:

To achieve the set goal of secure steganography, model proposed by [76] which is a consequent of the research presented in [77] and [78] respectively is preferred. The researchers, however, have opted for parallel processing to induce randomness for pixels (in range 0 to 63) that remained unaltered during bit embedding process as shown in Fig. 6.

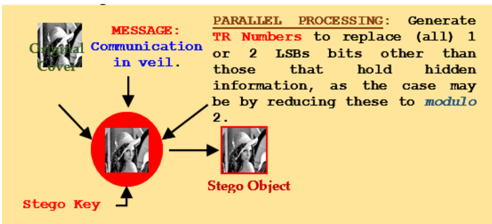

Fig. 6. New Steganographic Model for LSB Image Steganography

7) Parallel Processing of Cover:

In order to poise the effect of substitution latent uncertainty was induced by generating one/two random bits using Stego key dependent Pseudo Random Number Generator (PSNR) that gets substituted as LSBs for those pixel that fall under OFF/'0' Stego key bits (as explained in lateral discussion) during bit embedding process.

8) Pseudo Random Number Generator (PRNG):

Fig. 7 explicate on the PSNR used during bit embedding and extraction process further details of which are beyond the scope of this paper.

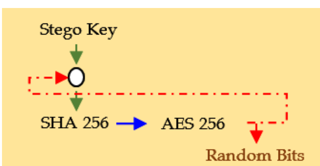

Fig. 7. Pseudo Random Bit Generation Process

V. Proposed Algorithm

A. Information Embedding Process

a) Select cover Image.

b) Select secret file that is to be hidden inside selected cover.

c) Determine HASH of secret file and encrypt the same using sender's private key.

d) Join secret message length, file's extension along with its digital signature (encrypted HASH) and affix it as message header at the beginning of the secret message.

e) Exclusive-Or the outcome of step (d) with Stego key.

f) Outcome of preceding step serves as "ready-to-get-embedded inside cover" information.

g) Compute and store as follows:

b1(i-1)=(Stego.Key(i-1)+Stego.Key(i)) MOD 2+1, i=1 ... 31 ... (1)

b1(31)=(Stego.Key(0)+Stego.Key(31)) Mod 2 +1 ... (2)

i.e., b1(0..31) = 1 or 2, indicates how many LSBs of selected target locations in original cover are to be replaced with secret message bits.

Note: For 1-bit implementation, MOD 2 + 1 be replaced with MOD 2, where no LSB substitution for b1(i)=0.

h) Select a 256-bit random secret Stego key and translate it into its equivalent binary. Concatenate 256 Stego key bit blocks one after another till that length becomes equal to or greater than the length of the cover file.

i) Calculate Stego key dependent random pixel within the selected cover using equations (3) and (4).

$$d = (d + \sum_{i=0}^{31} \left(Stego.key_i^3 \right) \bmod 65535) \bmod 65535 + 1 \qquad \ldots \ldots \ldots (3)$$

$$d = Length.of.Cover / d + 1 \qquad \ldots \ldots \ldots (4)$$

j) Starting from the random pixel 'd 'traverse the cover file sequentially but in cyclic order just before the pixel 'd 'while performing the following steps:

- Find pixel value in range 3 to 66.
- Take the binary bits of Stego key blocks one-by-one and for ON/'1' bit, check in sequence, the number of bits corresponding to b (i) where i = 0 to 31. Take the same number of secret message bits and substitute those at LSB position(s) of targeted pixel. The index 'i' gets reinitialized to zero if secret bits are still left for embedding. Terminate bit embedding process once all secret bits get exhausted.
- Repeat the process till the secret file get hidden inside the cover image file.

B. Bit Extraction Process

a) Select Stego object.

b) Select pre agreed secret 256 bit Stego key and convert it into its equivalent binary.

c) Compute and store as given in Sec. V (A)(g).

d) Calculate Stego key dependent random pixel within the selected cover as given in para (i) of Sec. V (A).

e) Taking the value of 'd' form preceding step perform the following till extraction of 96 bits i.e., hidden message header:

- Find pixel value in range 0 to 63.
- Take the binary bits of Stego key blocks one-by-one and for its ON/'1' bit check in sequence the number of bits corresponding to b (i) where i = 0 to 31. Extract (and thereafter concatenate) the same number of bits from target pixel of Stego object.
- Aforesaid process be repeated up to length of message (8 x message length) arrived at via message header explained subsequently.
- Outcome i.e., 96 bits from preceding step gets exclusive-Or (XoR) with Stego key which gives concealed header.
- Extract hidden message's HASH using sender's public key and the outcome be stored for subsequent usage.

- Compute HASH of the extracted hidden information.
- If the computed HASH equates to one obtained from then non-repudiation of the sender also gets established besides confirming the integrity of hidden information.
- Store the extracted bits in a file (which was hidden in the cover image). Assign it a name and post fix the extracted extension (from the header) to it.

C. Illustration

Following is a step by step illustration of secret message bits embedding and extraction process using "Parrot.Jpg"- well-known in image processing, which along with its histogram appears in Fig. 8.

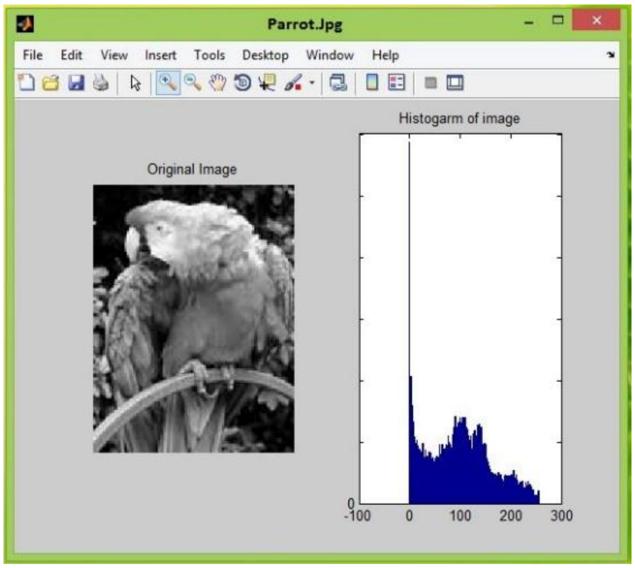

Fig. 8. Image Parrot.jpg along with its Histogram

1) Bit Hiding Process

- Let Fig. 9 represent a portion of the cover image for exemplification purpose where encircled in red are the possible target pixel values for holding secret message bits.
- Let the secret message be "Al-Awra" comprising of 7 characters which in terms of number of bits equate to 56 (7 x 8). The message is of type "Text", its binary equivalent is: "01000001- 01101100- 00101101- 01000001- 01110111- 01110010- 01100001" for corresponding ASCII values "65, 108, 45, 65, 119, 114, and 97" respectively. Computed HASH (SHA 256) of the message in hexadecimal Format (to be encrypted using Sender's Private key) is as under:

  "c58c23e9aad108e423e2ad0ccb261c7563e03f
  b9a6a31217aa25c2cb905640d7"

- The first four bytes of computed HASH shall be a part of message header.
- Let the secret 256-bit Stego key in hexadecimal format be as follows:

  3F613BCD5AF1FCA223EC42477DA7CD7CAE425
  439B3CA1A15405980D0C0BAE464

115	118	121	12	122	123	15	17	19	130	132	135	137	142	36	146
43	45	155	158	46	43	45	151	154	155	151	152	153	44	42	147
152	40	149	153	153	43	45	44	46	46	41	40	151	42	151	41
41	149	41	38	38	40	40	148	36	145	149	37	38	38	146	37
37	39	40	147	147	37	148	148	41	39	146	149	39	148	39	42
148	147	34	149	150	150	148	40	42	149	149	41	45	152	152	152
40	152	41	42	151	41	41	150	39	39	148	38	146	39	147	40
37	39	37	147	147	148	147	39	144	144	146	41	39	41	41	39
149	150	38	40	148	42	149	40	150	149	39	41	150	41	148	146
39	40	147	39	39	39	148	146	39	39	41	39	38	148	37	36
143	35	37	144	142	142	34	33	35	144	143	37	144	35	30	37
35	142	142	143	143	35	34	143	36	144	143	142	144	35	36	37
35	147	146	145	39	147	145	144	37	35	146	35	145	145	147	37
147	147	146	37	38	147	41	36	37	148	39	39	147	35	145	37
39	39	39	41	36	148	39	39	42	42	39	41	149	148	146	39
147	36	38	147	148	39	145	35	145	37	146	37	146	38	147	145
130	155	46	145	39	149	39	144	149	39	144	144	35	148	42	37
132	151	41	149	146	149	148	146	39	41	143	143	146	39	39	146
135	152	40	37	149	41	38	41	41	39	37	142	35	39	41	37
137	153	151	38	39	45	146	39	150	38	144	144	145	147	149	146
142	44	42	38	148	152	39	41	41	148	35	35	145	35	148	38
36	42	151	146	39	152	147	41	148	37	30	36	147	145	146	147
146	147	41	37	42	152	40	39	146	36	37	37	37	37	39	145
19	154	46	36	41	42	39	144	150	39	35	36	37	37	42	145
17	151	44	148	148	40	150	39	40	146	33	143	144	36	39	35
15	45	45	40	148	148	41	147	149	148	34	34	145	41	39	145
123	43	43	40	37	150	41	148	42	39	142	35	147	147	148	39
122	46	153	38	147	150	151	147	148	39	142	143	39	38	36	148
12	158	153	38	147	149	42	147	40	39	144	143	145	37	41	147
121	155	149	41	40	34	41	37	38	147	37	142	146	146	39	38
118	45	40	149	39	147	152	39	150	40	35	142	147	147	39	36
115	43	152	41	37	148	40	37	149	39	143	35	35	147	39	147

Fig. 9. Randomly Extracted Darkish Portion of the Cover Image

- Binary equivalent of which is as follows:

  00111111 01100001 00111011 11001101 01011010 11110001 11111100 10100010 00100011 11101100 01000010 01000111 01111101 10100111 11001101 01111100 10101110 01000010 01010100 00111001 10110011 11001010 00011010 00010101 01000000 01011001 10000000 11010000 11000000 10111010 11100100 01100100

I) Equations (1) and (2) render the following numbers for bit substitution by operating on the Stego key, which is an input to bit embedding process:

1 1 1 2 2 2 1 2 2 1 2 1 1 1 2 1 1 1
2 1 2 1 2 2 2 2 1 1 1 1 1 2

i.e., 32 target pixels shall hide 46 encrypted bits.

II) From equations (3) and (4), 'd' is computed as 33130 for 512 pixel values, and is indicated in blue in Fig. 10.

- *From preceding steps, the message header takes the form as follows ("-" is only used for clarity):*

  7 46-84-88-84 197-140-35-233

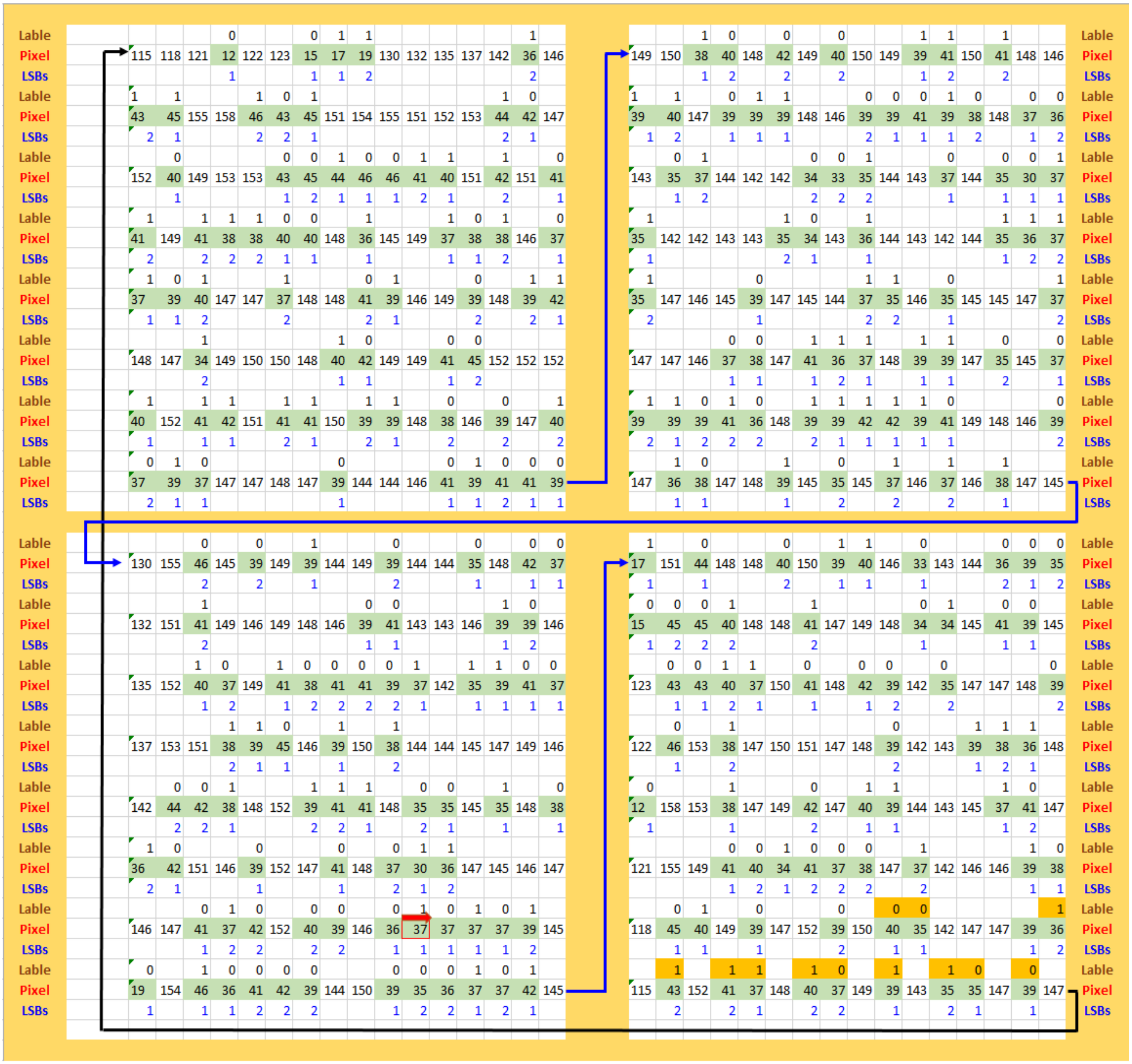

Fig. 10. Illustrating Target Locations along with Number of Secret Bits for Embedding

Fig. 10 depicts the target pixels labeled as '1' where number of bits to be hidden is written immediately below–the respective target pixel value. Pixels labelled as '0' are *don't embed* locations whose one/two LSBs will be randomly populated using PRNG in parallel with actual encrypted bit embedding processing.

- Affixing header with the secret message takes the following form when represented in binary form and totals 152 bits:

- 0000000000000000000000000000000111001011100101010001011000010101001100010110001100001000111110100101000001011011000010110101000001011101110111001001100001

This gets '*Exclusive Or'* (XoR) with the stego key bits as follows:

```
  00111111011000010011101111001101010110
⊗ 00000000000000000000000000000111001011
  00111111011000010011101111001010011101
  10111100011111110010100010001000111110
⊗ 10010101000101100001010100110001011000
  00101001011010010011110110111001100110
  11000100001001000111011111011010011111
⊗ 11000010001111101001010000010110110000
  00000110000110101110001111001100101111
  00110101111100101011100100001001010100
⊗ 10110101000001011101110111001001100001
  10000000111101110110010011000000110101
```

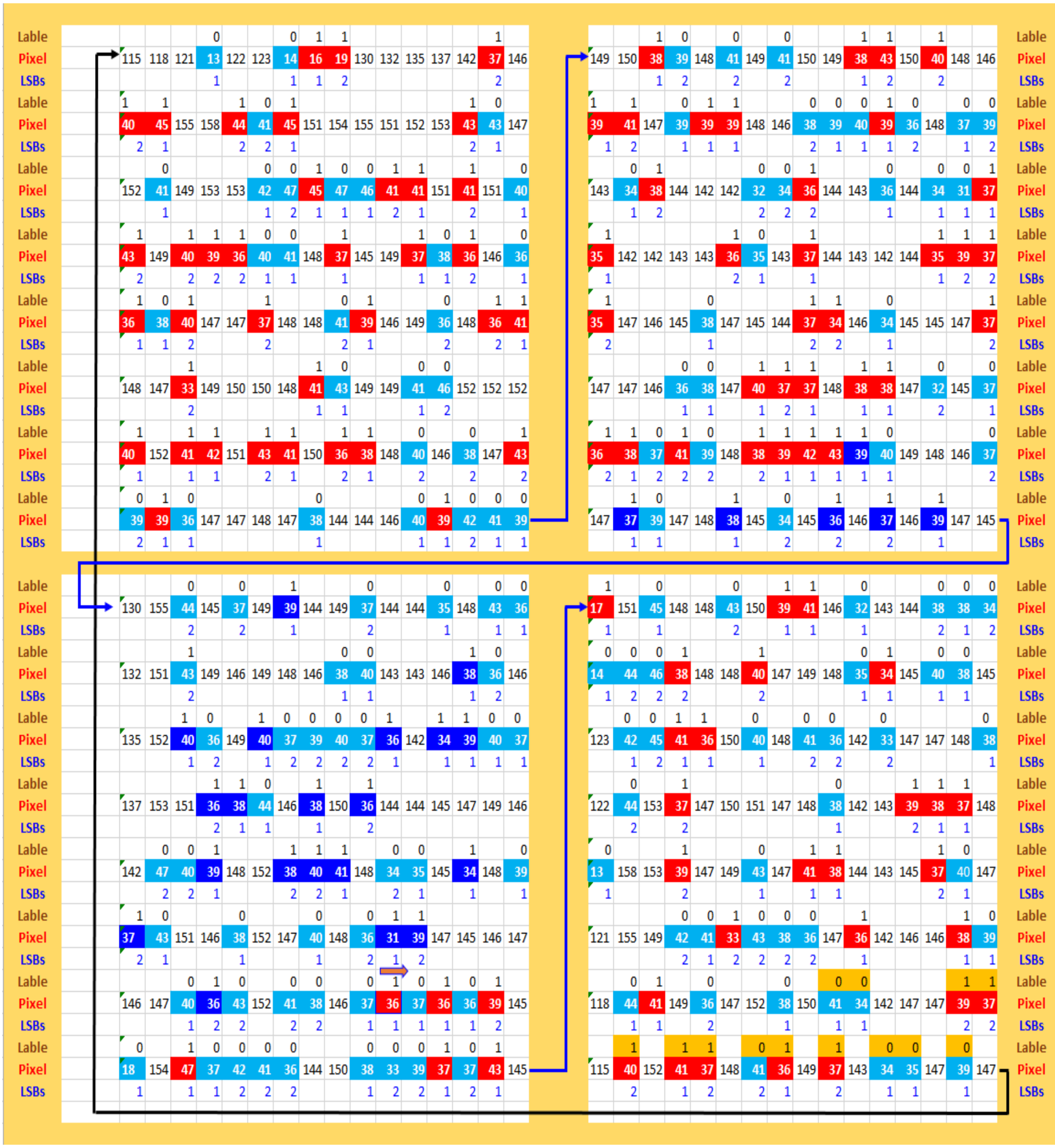

Fig. 11. Illustrating Outcome of Bit Embedding Process

and the outcome (given below) serves as ready-to-embed encrypted secret bits:

```
00111111011000010011101111100101001 1101
```

- Following is the Stego key dependent splitting of encrypted message bits (with Header inclusive) for substituting the LSBs of target pixels in the cover on the analogy portrayed vide Fig. 9.

0 0 11 1 1 1 1 0 1 10 00 0 1 0 01 11 0 1 11 1 0 01 01 0 0 1
11 01 00 1 01 0 01 0 11 01 00 1 00 1 11 1 01 1 01 11 00 11
00 1 1 00 0 00 01 1 00 0 01 1 0 1 0 11 1 00 0 11 1 1 0 0 11
00 1 01 1 1 1 10 00 0 0 00 1 1 11 01 11 01 10 01 0 01 1 0 0
00 0 01 10 1 0 1

115	118	121	13	122	123	14	16	19	130	132	135	137	142	37	146
40	45	155	158	44	41	45	151	154	155	151	152	153	43	43	147
152	41	149	153	153	42	47	45	47	46	41	41	151	41	151	40
43	149	40	39	36	40	41	148	37	145	149	37	38	36	146	36
36	38	40	147	147	37	148	148	41	39	146	149	36	148	36	41
148	147	33	149	150	150	148	41	43	149	149	41	46	152	152	152
40	152	41	42	151	43	41	150	36	38	148	40	146	38	147	43
39	39	36	147	147	148	147	38	144	144	146	40	39	42	41	39
149	150	38	39	148	41	149	41	150	149	38	43	150	40	148	146
39	41	147	39	39	39	148	146	38	39	40	39	36	148	37	39
143	34	38	144	142	142	32	34	36	144	143	36	144	34	31	37
35	142	142	143	143	36	35	143	37	144	143	142	144	35	39	37
35	147	146	145	38	147	145	144	37	34	146	34	145	145	147	37
147	147	146	36	38	147	40	37	37	148	38	38	147	32	145	37
36	38	37	41	39	148	38	39	42	43	39	40	149	148	146	37
147	37	39	147	148	38	145	34	145	36	146	37	146	39	147	145
130	155	44	145	37	149	39	144	149	37	144	144	35	148	43	36
132	151	43	149	146	149	148	146	38	40	143	143	146	38	36	146
135	152	40	36	149	40	37	39	40	37	36	142	34	39	40	37
137	153	151	36	38	44	146	38	150	36	144	144	145	147	149	146
142	47	40	39	148	152	38	40	41	148	34	35	145	34	148	39
37	43	151	146	38	152	147	40	148	36	31	39	147	145	146	147
146	147	40	36	43	152	41	38	146	37	36	37	36	36	39	145
18	154	47	37	42	41	36	144	150	38	33	39	37	37	43	145
17	151	45	148	148	43	150	39	41	146	32	143	144	38	38	34
14	44	46	38	148	148	40	147	149	148	35	34	145	40	38	145
123	42	45	41	36	150	40	148	41	36	142	33	147	147	148	38
122	44	153	37	147	150	151	147	148	38	142	143	39	38	37	148
13	158	153	39	147	149	43	147	41	38	144	143	145	37	40	147
121	155	149	42	41	33	43	38	36	147	36	142	146	146	38	39
118	44	41	149	36	147	152	38	150	41	34	142	147	147	39	37
115	40	152	41	37	148	41	36	149	37	143	34	35	147	39	147

Fig. 12. Stego Object (Image's Pixel Values) Carrying Hidden Information

- Fig. 11 shows the outcome of bit embedding where pixels values enclosed in red square contains hidden message bits. Pixels that are under label '1' but does not carry hidden data together with those that fall under label '0' are enclosed in color other than white. These are the pixels values whose 1 or 2 LSBs are substituted with randomly generated 1 or 2 binary bits using Stego key dependent PRNG.

2) *Bit Extraction Process*

- Let the received Stego object byte values be as shown in Fig. 12.

- The pre agreed secret Stego key is **3F613BCD5AF1FCA223EC42477DA7CD7CAE425439B3CA1A15405980D0C0BAE464**, its corresponding binary equivalent bits and 1 or 2 bit patterns obtained via equations (3) and (4) are:

1) *Binary equivalent Bits:*

```
00111111 01100001 00111011 11001101
01011010 11110001 11111100 10100010
00100011 11101100 01000010 01000111
01111101 10100111 11001101 01111100
10101110 01000010 01010100 00111001
10110011 11001010 00011010 00010101
01000000 01011001 10000000 11010000
11000000 10111010 11100100 01100100
```

2) *1 or 2 Bit Patterns for Hidden Bits Extraction:*

```
1 1 1 2 2 2 1 2 2 1 2 1
1 1 2 1 1 1 2 1 2 1 2 2
2 2 1 1 1 1 1 2
```

- The random Stego key dependent starting point with in stego object for bit extraction obtained via equations (5) and (6) respectively is $d = 33130 \bmod 512 + 1 = 363$, where 512 is the length of Stego object (File).

- In order to extract only the required hidden information and to avoid unnecessary processing of irrelevant data it is ought to first extract 96 bits of hidden message Header that gives hidden information's length, its type, and expected HASH. Hence, commencing from pixel $d = 363$ and proceeding forward in cyclic order the first 96 hidden LSBs of targeted pixels gets extracted using procedure explained bit hiding process and as illustrated in Fig. 13.

1) *Hidden Extracted LSBs f targeted pixels:*

```
0 0 11 1 1 1 1 0 1 10 00 0 1 0 01 11 0 1 11 1 0 01 01 0
0 1 11 01 00 1 01 0 01 0 11 01 00 1 00 1 11 1 01 1 01
11 00 11 00 1 1 00 0 00 01 1 00 0 01 1 0 1 0 11 1 00 0
11 1 1 0 0 11 00 1 01 1 1 1 10 00 0 0 00 1 1 11 01 11
01 10 01 0 01 1 0 0 00 0 01 10 1 0 1
```

2) *Extracted hidden bits are then XoR with first 96 bits of Stego key that yields message's:*

Length (i.e., 7)

```
  0011111101100001 0011101111001101
⊗ 0011111101100001 0011101111001010
  0000000000000000 0000000000000111
```

Type (i.e., .TXT)

```
  0101101011110001 1111110010100010
⊗ 0111010010100101 1010010011110110
  0010111001010100 0101100001010100
```

HASH (i.e., First four Hex bytes: c58c23e9)

```
  0010001111101100 0100001001000111
⊗ 1110011001100000 0110000110101110
  1100010110001100 0010001111101001
```

3) *After extracting and decrypting Header information the process continues for the next 56 bits which are then XoR with Stego key bits from 97th bit onwards as shown below.*

```
  01111101 10100111 11001101
⊗ 00111100 11001011 11100000
  01000001 01101100 00101101

  01111100 10101110 01000010
```

⊗ 00111101 11011001 00110000
01000001 01110111 01110010
01010100
⊗ 00110101
01100001

i.e.

01000001 01101100 00101101
01000001 01110111 01110010
01100001

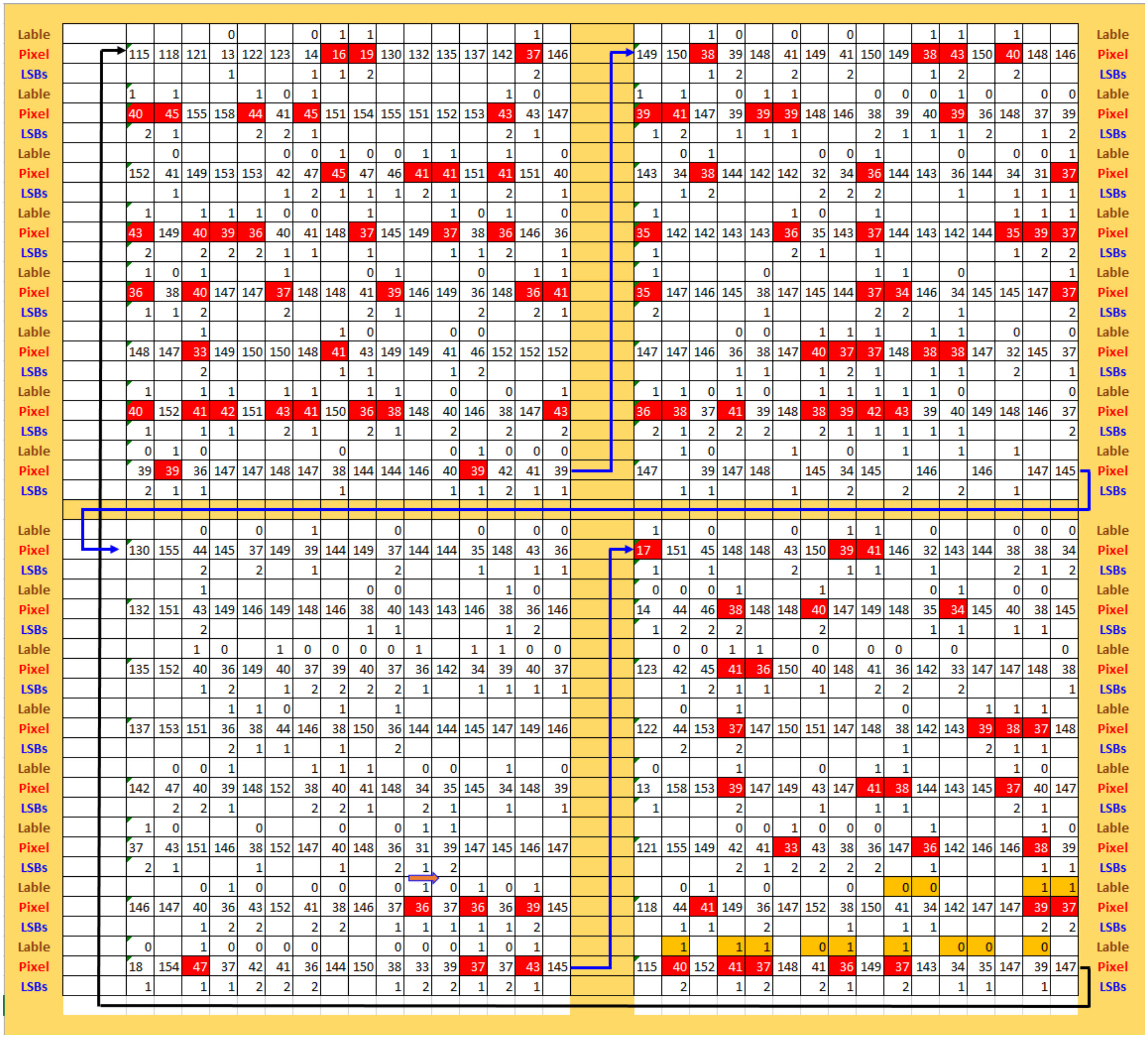

Fig. 13. Hidden Bits Extraction Process

4) The resultant bits are concatenated in chunks of length 8 each, and are then translated into equivalent ASCII character codes as "Al-Awra", that are saved in a file having extension ".TXT".

5) To confirm on the integrity and non-repudiation of message/hidden information the received contents are subjected to SHA-256 HASH algorithm (followed by its decryption using Originator's Public key) the outcome of which is

"c58c23e9aad108e423e2ad0ccb261c7563e03fb9a6a31217aa25c2cb905640d7"

, where the first four bytes are the same as that extracted from hidden message's header thereby affixing on the legitimacy of the message as well as of its sender.

Mean, variance and standard deviation for the aforesaid illustration were computed as given in Table 2 while its graphical representation are as shown in Fig. 14 respectively.

Mean square error and Peak signal-to-noise ratio of the cover and stego object are as shown in Table 3.

TABLE II. MEAN, VARIANCE AND STANDARD DEVIATION FOR COVER AND STEGO OBJECT

OUTCOME	Cover Pixels	Stego Object
Mean	0.8910938	0.8897656
Variance	29.2351052	29.3776853
Standard Deviation	0.540695	0.5420119

TABLE III. MSE AND PSNR FOR COVER AND STEGO OBJECTS

Image	Dim	LSBs	MSE	PSNR
Lena.jpg	512 x 512	1	0.499097936447318	51.1489458661669
		2	2.49174973991598	44.1657593926575
Monalisa.jpg		1	0.498689440540415	51.1525018848588
		2	2.53367308343121	44.0932978316228
Parrot.jpg		1	0.503298725650196	51.1125453010079
		2	2.51557345741172	44.1244335716171

VI. TEST RESULTS

Fore test purposes we selected three freely available (on web) 512 x 512 sized 8-bit gray scaled "jpg" images as shown in Fig. 15.

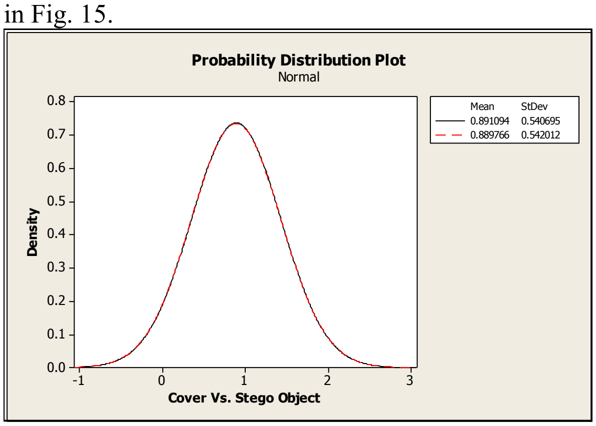

Fig. 14. Contrasting Cover and Stego Object

Lena.jpg *Monalisa.jpg* *Parrot.jpg*

Fig. 15. Test Images

"Communication in veil." was our secret message that equals 176 bits in total and was concatenated with 96 bits of header information. We opted to test the efficiency of our proposed solution by observing the quantified effect of 1 and 2-bit LSB change induced by bit embedding on the selected cover (image). In this connection cover image, parallel processed Cover and Stego object were subjected to two of the five full-reference algorithms that serves as fundamental components of Image Quality Assessment (IQA) [79] delineated subsequently, and the source code of which is available at [80]:

a) Mean Squared Error (MSE): Depicts the amount of biasing in an image. It is computed using formula as shown in equation (5), where the higher the value of MSE the higher will be the distortion.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left(Y_i - \tilde{Y}_i\right)^2 \qquad \textbf{(5)}$$

b) Peak Signal-to-Noise Ratio (PSNR): As the name implies PSNR is the ratio between extreme power (possible value) of a signal and the power of garbling noise that affects the quality of that signal. The formula for computing PSNR is as shown in equation (6):

$$PSNR = 20\log_{10}\left(\frac{MAX}{\sqrt{MSE}}\right) \qquad \textbf{(6)}$$

- The effect is graphically elucidated by plotting the probability distribution graph of the original (image) cover and parallel processed cover/stego object (for the three images referred in Fig. 15) using Minitab 16 [81] as illustrated in Fig. 16-21, via computing their mean, variance and standard deviation shown in table 4 respectively.

TABLE IV. MSE AND PSNR FOR COVER AND STEGO OBJECTS

Lena.jpg		Mean	Variance	Standard Deviation
Original Image		1.2404707	22.6704645	0.4761351
Stego Object	1	1.2404602	22.6773109	0.476207
	2	1.2403668	22.6849972	0.4762877

Monalisa.jpg		Mean	Variance	Standard Deviation
Original Image		0.5603488	16.0417024	0.4005209
Stego Object	1	0.5604179	16.0390902	0.4004883
	2	0.5605014	16.0517136	0.4006459

Parrot.jpg		Mean	Variance	Standard Deviation
Original Image		0.9716536	40.1667786	0.6337727
Stego Object	1	0.9718385	40.1481114	0.6336254
	2	0.9718984	40.1030232	0.6332695

VII. DELUSION ASSOSIATED WITH COVER CAPACITY IN CONTEXT OF SECURE COMMUNICATION

Since inception of digital steganography, images have remained a preferred choice for cover or as hidden information carrier by virtue of having the Meta data / redundant associated information (purely in terms of bit's significance towards overall appearance). However, in context of security, a digital object with more of hidden information may indirectly explicate on bit embedding algorithm especially when the same cover is repeatedly used as carrier in communication. [82] acmes on the implication of putting more information online that needs to be taken seriously in its eternity while evolving secure steganographic schemes or other security system.

VIII. Technical Analysis

Let $\varepsilon(\theta)$ denotes the entropy of Cover Image while $\varepsilon(\varphi)$ represents that of the Stego Object. Clearly if $\varepsilon(\theta) = \varepsilon(\varphi)$ after bit hiding then it implies that original Cover remains unaffected by the bit embedding process which, however, is a rare case to occur. Hence, for all remaining cases, $\varepsilon(\theta) \neq \varepsilon(\varphi)$ implies that the difference between Cover and Stego Object point towards hidden information i.e., $\varepsilon(\theta) - \varepsilon(\varphi) =$ Hidden

IX. Advantages

Following are some of the advantages of proposed scheme:

a) Secure

b) Aptness for colored images.

X. Future Work

a) Bench marking of gray scaled Images that are suitable as Cover for the proposed data hiding scheme.

b) Research work on AVI Steganography based on proposed scheme is in process.

XI. Conclusion

This research endeavor is This research endeavor is amongst those of the few image based steganographic schemes that does not necessitate on having original (cover) image at receiver's end for extracting hidden information while use of TRNG distinct it from the rest of its counterparts. A salient feature of the proposed scheme is that it is equally suitable for gray scaled and as well as for colored images (when implemented for 'B' – Blue color). It can be easily inferred from the test results that secret message is diffused in the cover, by virtue of preprocessing of image and random scattering of message bits, in such a manner that attacker may not even precise as to whether or not the image carries some hidden information. All of the foresaid traits raises the probability for Wendy to commit Type II error which is desirous for any steganographic scheme.

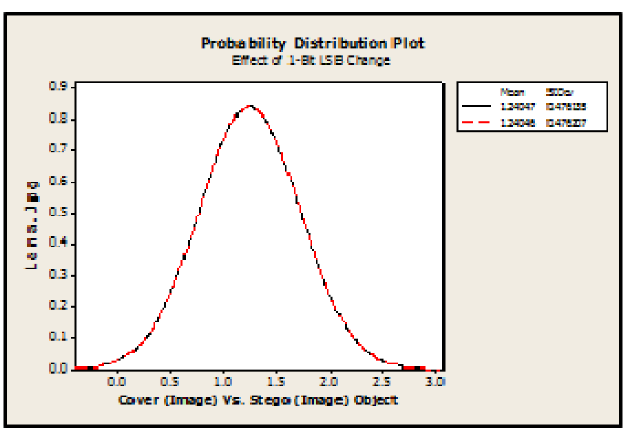

Fig. 16. Original Cover Vs, Stego Object for 1-Bit LSB Change

Information either with or without using encryption, and as apparent is unsecure. So in order for secure steganography to prevail, we ought to devise some scheme such that $\varepsilon(\theta) - \varepsilon(\varphi)$ does not point directly towards hidden information i.e., $\varepsilon(\theta) - \varepsilon(\varphi) = \delta(\square)$, where $\square$ represents a mix of hidden information and statistically related random bits arrived at via some random source/process under control of Stego key $\delta(\square) = E_{mbed}$(StegoKey, Secret Data/Information, Random.Bits=μ(Random)), which is also analogous to Kerckhoff's Principle.

It is apparent that our proposed methodology is in confirmation with the aforesaid argument and hence poses a hard to solve problem for Wendy constraint only by the time and resources she is willing to invest.

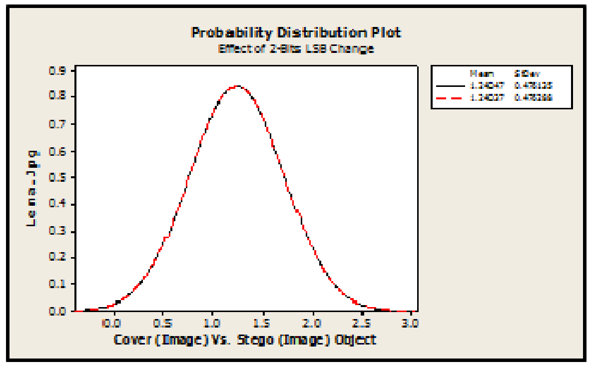

Fig. 17. Original Cover Vs, Stego Object for 2-Bits LSB Change

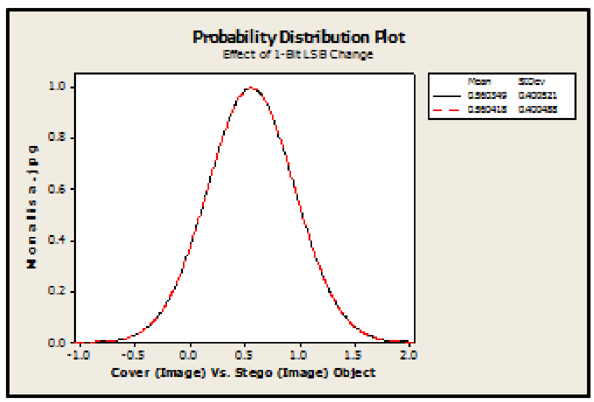

Fig. 18. Original Cover Vs, Stego Object for 1-Bit LSB Change

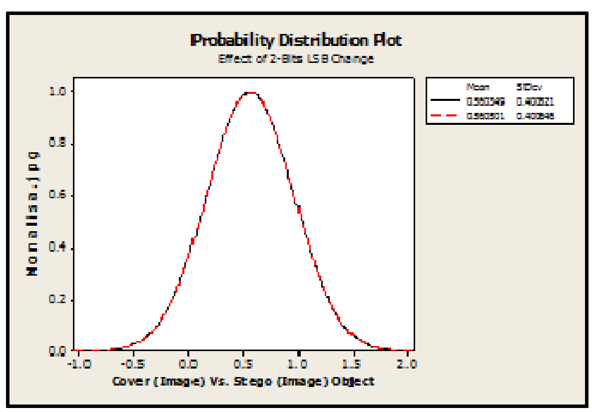

Fig. 19. Original Cover Vs, Stego Object for 2-Bits LSB Change

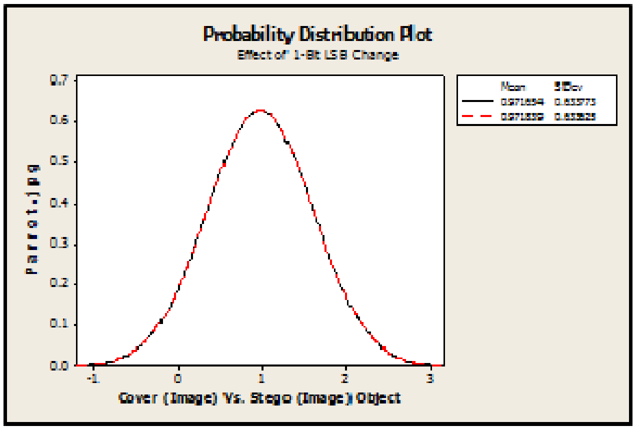

Fig. 20. Original Cover Vs, Stego Object for 1-Bit LSB Change

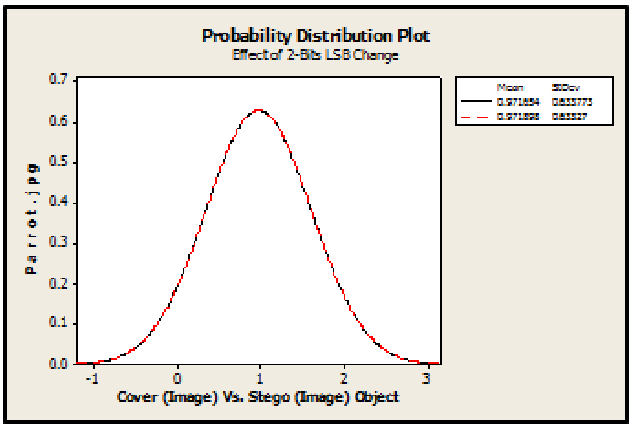

Fig. 21. Original Cover Vs, Stego Object for 2-Bits LSB Change

REFERENCES

[1] The Oxford English dictionary: being a corrected re-issue, Clarendon Press, Oxford, 1933.

[2] Stefan Katzenbeisser and Fabien A.P. Petitcolas, Introduction to information hiding. In Information Hiding: Techniques for Steganography and Digital Watermarking, Artech House. 1-14, Boston: 2000.

[3] Krista Bennett, "Linguistic Steganography: Survey, Analysis, And Robustness Concerns For Hiding Information In Text", Cerias Tech Report 2004-13, Center for Education and Research in Information Assurance and Security, Purdue University, West Lafayette, IN 47907-2086

[4] Khan Farhan Rafat and Muhammad Sher, An Eccentric Scheme for Oblivious Communication. International Journal of Computer Science Issues (IJCSI). Volume 10, Issue 4, No. 2, July 2013, Pp. 89-96. www.ijcsi.org Impact Factor 0.242

[5] Neil F. Johnson, Sushil Jajodia,"Exploring Steganography: Seeing the Unseen", IEEE 0018-9162/98. 1998.

[6] Chincholkar A.A. and Urkude D.A. Design and Implementation of Image Steganography. Journal of Signal and Image Processing, Volume 3, Issue 3, pp. 111-113, 2012.

[7] B. Ptzmann, Information hiding terminology. In Anderson [5], pp. 347-350, ISBN 3-540-61996-8, results of an informal plenary meeting and additional proposals.

[8] G. J. Simmons, The prisoners' problem and the subliminal channel. In Advances in Cryptology: Proceedings of Crypto 83 (D. Chaum, ed.), Plenum Press, pp. 51–67, 1984.

[9] Mohammed Salem Atoum, Osamah Abdulgader Al- Rababah, Alaa Ismat Al-Attili, New Technique for Hiding Data in Audio File. International Journal of Computer Science and Network Security (IJCSNS), Vol.11 No.4, pp. 173-177, April 2011.

[10] Gregory Kipper. Investigator's Guide to Steganography. Auerbach Publications, pp. 240, October 2003.

[11] Jenny Shearer, Peter Gutmann, Government, Cryptography, and the Right to Privacy. Journal of Universal Computer Science (JUCS), Volume 2, No.3, pp. 113-135, March 1996.

[12] WIPO Copyright Treaty, 1996.

[13] Document prepared by the International Bureau, WIPO/INT/SIN/98/9, 1998. Presented at the WIPO Seminar for Asia and the Pacific Region on Internet and the Protection of Intellectual Property Rights, Singapore.

[14] T. Aura, "Invisible Communication," EET 1995, technical report, Helsinki Univ. of Technology, Finland, Nov. 1995; http://deadlock.hut.fi/ste/ste_html.html.

[15] Rafael C. Gonzalez and Richards E. Woods, Digital Image Processing, 3rd Edn., PEARSON Prentice Hall.

[16] Owens, M., "A discussion of covert channels and steganography", SANS Institute, 2002.

[17] Raydhitya Yoseph, PSNR Comparison When Using LSB Steganography on Each RGB Color Component, IF 3058 Cryptography – Sem. II Year 2012/2013

[18] Moerland, T., "Steganography and Steganalysis", Leiden Institute of Advanced Computing Science, www.liacs.nl/home/ tmoerl/privtech.pdf

[19] Silman, J., "Steganography and Steganalysis: An Overview", SANS Institute, 2001.

[20] Lee, Y.K. & Chen, L.H., "High capacity image steganographic model", Visual Image Signal Processing, 147:03, June 2000.

[21] Juan José Roque and Jesús María Minguet, SLSB: Improving the Steganographic Algorithm LSB.

[22] Wu, D.C., Tsai, W.H. "A Steganographic method for images by pixel-value differencing," Pattern Recognition Letters 24 (June), 2003, pp. 1613–1626.

[23] Saad M. A. Al-Momen, Loay E. George. "Image Hiding Using Magnitude Modulation on the DCT Coefficients." Journal of Applied Computer Science & Mathematics, No. 8 (4), Suceava, pp. 9-14, 2010.

[24] Thekra Abbas, Zou Beiji, Maan Younus Abdullah. "Information Security Technique in Frequency Domain." International Journal of Digital Content Technology and its Applications (JDCTA), Volume 5, doi:10.4156/jdcta.vol5.issue12.35, pp. 279-289, December 2011.

[25] H S Manjunatha Reddy, High Capacity and Security Steganography Using Discrete Wavelet Transform, International Journal of Computer Science and Security (IJCSS), Volume (3): Issue (6).

[26] Bender, W., Gruhl, D., Morimoto, N. & Lu, A. "Techniques for data hiding", IBM Systems Journal, Vol 35, pp. 313-336.1996.

[27] Neil F. Johnson and Sushil Jajodia. "Steganalysis of Images Created Using Current Steganography Software." Lecture Notes in Computer Science, Springer-Verlag, Vol. 1525, pp. 273-289, 1998.

[28] Marvel, L.M., Boncelet Jr., C.G. & Retter, C. "Spread Spectrum Steganography", IEEE Transactionson image processing, pp. 8:08, 1999.

[29] Cachin, C., An Information-Theoratic Model for Steganography, in Proceedings of the Second International Workshop on Information Hiding, vol. 1525 of Lecture Notes in Computer Science, pp. 306-31, Springer, 1998.

[30] Bin Li, Junhui He, Jiwu Huang, Yun Qing Shi. A Survey on Image Steganography and Steganalysis. Journal of Information Hiding and Multimedia Signal Processing, Vol. 2, pp. 142-172, April 2011.

[31] A. Westfeld and A. Pfitzmann. Attacks on steganographic systems, in Proc. 3rd Int. Workshop on Information Hiding, vol. 1768, pp.61–76, 1999.

[32] Federal Aviation Administration. "Hearing and Noise in Aviation." Internet: http://www.faa.gov/pilots/safety/pilotsafetybrochures/media/hearing_brochure.pdf

[33] R. Z. Wang, C. F. Lin, and J. C. Lin, "Hiding data in images by optimal moderately significant bit replacement," IET Electronics Letters, vol. 36, no. 25, pp. 2069-2070, 2000.

[34] R. Z. Wang, C. F. Lin, and J. C. Lin, "Image hiding by optimal LSB substitution and genetic algorithm," Pattern Recognition, vol. 34, pp. 671-683, 2001.

[35] C. K. Chan and L. M. Cheng, “Improved hiding data in images by optimal moderately-significant-bit replacement,” IEE Electronics Letters, vol. 37, no. 16, pp. 1017-1018, 2001.

[36] C. C. Chang and H. W. Tseng, “A steganographic method for digital images using side match,” Pattern Recognition Letters, vol. 25, pp.1431-1437, 2004.

[37] C. K. Chan and L. M. Cheng, “Hiding data in images by simple LSB substitution,” Pattern Recognition, vol.37, pp. 469-474, 2004.

[38] C. C. Chang, J. Y. Hsiao, and C. S. Chan, “Finding optimal least-significant-bit substitution in image hiding by dynamic programming strategy,” Pattern Recognition, vol. 36, pp.1538-1595, 2003.

[39] C. C. Chang, C. S. Chan, and Y. H. Fan, “Image hiding scheme with modulus function and dynamic programming strategy on partitioned pixels,” Pattern Recognition, vol. 39, no. 6, pp. 1155-1167, 2006.

[40] C. C. Chang, M. H. Lin, and Y. C. Hu, “A fast and secure image hiding scheme based on lsb substitution,” International Journal of Pattern Recognition and Artificial Intelligence, vol. 16, no. 4, pp. 399-416, 2002.

[41] C. C. Thien and J. C. Lin, “A simple and high-hiding capacity method for hiding digit-by-digit data in images based on modulus function,” Pattern Recognition, vol. 36, pp. 2875-2881, 2003.

[42] A. Ker, “Steganalysis of LSB Matching in Gray scale Images,” IEEE Signal Processing Letter, vol. 12, no.6, pp. 441-444, June 2005.

[43] W. Luo, F. Huang, and J. Huang, “Edge adaptive image steganography based on LSB matching revisited,” IEEE Transactions on Infomation Forensics Security, vol. 5, no. 2, pp.201 -214, 2010.

[44] Fridrich, J., Steganography in Digital Media: Principles, Algorithms, and Applications, Cambridge University Press (2009).

[45] J. Mielikainen, “LSB matching revisited,” IEEE Signal Processing Letters, vol. 13, no. 5, pp. 285-287, 2006.

[46] X. Li, B. Yang, D. Cheng, and T. Zeng, “A generalization of LSB matching,” IEEE SignalProcessing Letters, vol. 16, no. 2, pp. 69-72, 2009.

[47] D.C. Wu, W. H. Tsai (2003), “A Steganographic Method for Images by Pixel-Value Differencing”, Pattern Recognition Letter, Vol. 24, No. 9-10, p. 1613–1626.

[48] Westfeld and A. P¯Tzmann (1999), “Attacks on Steganographic Systems - Breaking the Steganographic Utilities Ezstego, Jsteg,Steganos, and S-tools-and Some Lessons Learned”, In Proceedings of the 3rd Information Hiding Workshop, volume 1768 of LNCS, pages 61-76. Springer, 1999.

[49] Niels Provos and Peter Honeyman (2002), “Detecting Steganographic Content on The Internet”. In Proceedings of NDSS'02: Network and Distributed System Security Symposium, pp1-13, Internet Society, 2002.

[50] Stanley, C.A. (2005), “Pairs of Values and the Chi-squared Attack”, in CiteSteer. 2005, pp. 1-45.

[51] Wen-Nung Lie, Li-Chun Chang (October 24-28, 1999), “Data hiding in images with adaptive numbers of least significant bits based on thehuman visual system.” In Proc. IEEE Int. Conf., Image Processing. Kobe (Japan), pp 286-290.

[52] Lee, Y. K., Chen, L. H. (2000), “High Capacity Image Steganographic Model”, IEEE Proc., Vis. Image Signal Process, Vol. 147, no. 3, p. 288-294.

[53] Cheng-Hsing Yang, Chi-Yao Weng, Shiuh-Jeng Wang, Hung-Min Sun (2008), “Adaptive Data Hiding in Edge Areas of Images with Spatial LSB Domain Systems”. IEEE Transactions on Information Forensics and Security, Vol. 3, No. 3, pp. 488-497.

[54] W. Luo , F. Huang and J. Huang (2010), “Edge Adaptive Image Steganography Based on LSB Matching Revisited", IEEE Trans. Inf. Forensics Security, vol. 5, no. 2, pp.201 -214.

[55] J. C. Joo, T. W. Oh, H. Y. Lee, H. K. Lee (Jan, 2011), "Adaptive Steganographic Method Using the Floor Function with Practical Message Formats,” International. Journal of Innovative Computing, Information and Control, Vol. 7, No. 1, pp. 161-175. ISSN 1349-4198.

[56] Mandal, J.K., Khamrui, A. (2011), "A Data-Hiding Scheme for Digital Image Using Pixel Value Differencing (DHPVD)", Electronic System Design (ISED), International Symposium, pp: 347 - 351.

[57] P. Mohan Kumar, K. L. Shunmuganathan (2012), “Developing a Secure Image Steganographic System Using TPVD Adaptive LSB Matching Revisited Algorithm for Maximizing the Embedding Rate”, Information Security Journal: A Global Perspective, Vol. 21, Issue 2.

[58] Youssef Bassil (December, 2012),"Image Steganography Based on a Parameterized Canny Edge Detection Algorithm”, International Journal of Computer Applications (0975 – 8887) Volume 60– No.4.

[59] Rocha, A. and Goldenstein, S. Steganography and steganalysis in digital multimedia: Hype or hallelujah? Journal of Theoretical and Applied Computing (RITA) 15, 1, pp. 83-110, 2008.

[60] A. Ker, “Derivation of error distribution in least squares steganalysis,” IEEE Transactions on Information Security and Forensics, vol. 2, pp.140–148, 2007.

[61] R. Du J. Fridrich and L. Meng, “Steganalysis of lsb encoding in color images,” Proceedings of IEEE International conference on Multimedia and Expo New York City, NY, Jul 30 - Aug2, 2000.

[62] M. Goljan J. Fridrich and R. Du, “Detecting lsb steganography in color and grey-scale images,” Magazine of IEEE multimedia, Special Issue on Security, October-November issue, 2001.

[63] X Wu S Dumitrescu and Z Wang, “Detection of lsb steganography via sample pair analysis,” IEEE Transactions on Signal Processing, vol. 51, No.7, pp. 1995–2007, 2003.

[64] Z. Tao and P. Xijian, “Reliable detection of lsb steganography based on the difference image histogram,” Proc. IEEE ICAAP, Part III, pp. 545–548, 2003.

[65] Q.Tang P.Lu, X.Luo and L.Shen, “An improved sample pairs method for detection of lsb embedding,” vol. 3200, pp. 116–127, 2004.

[66] A.D. Ker, “Improved detection of lsb steganography in greyscale images,” In: Proc. The 6th Information Hiding Workshop, Springer LNCS 3200, pp. 97-115, 2005.

[67] B. Liu X. Luo and F. Liu, “Improved rs method for detection of lsb steganography,” In: Proc. Information Security & Hiding (ISH 2005) workshop, Springer LNCS 3481, 508-516, 2005.

[68] A. Westfeld and A. Pfitzmann, "Attacks on Steganographic Systems", Proc. 3rd Information Hiding Workshop, Dresden, Germany, September 28-October 1, 1999, pp. 61-75.

[69] C. Yang X. Luo, Z. Hu and S. Gao, “A secure lsb steganography system defeating sample pair analysis based on chaos system and dynamic compensation,” Proceedings of International Conference, 2006.

[70] J. Fridrich and D. Soukal, “Matrix embedding for large payloads,” IEEE Transactions on Information Security and Forensics, vol. 7, pp. 12–17, 2008.

[71] Shreelekshmi R, M Wilscy and M Wilscy, "Preprocessing Cover Images for More Secure LSB Steganography," International Journal of Computer Theory and Engineering, Vol. 2, No. 4, pp. 546-551, August, 2010.

[72] Jessica Fridrich, Miroslav Goljan, and Rui Du,"Reliable Detection of LSB Steganography in Color and Grayscale Images"

[73] Khan Farhan Rafat and Muhammad Sher, On the Limits of Perfect Security for Steganography System. International Journal of Computer Science Issues (IJCSI). Volume 10, Issue 4, No. 2, July 2013, Pp. 121-126. www.ijcsi.org

[74] Boundary Detection Benchmark: Image anking, http://www.eecs.berkeley.edu/Research/Projects/CS/vision/bsds/bench/html/images.html

[75] Gadgi Sumangala, V R Kulkarni, Shridevi Sali, Sulabha Apte. “Performance Analysis of Sha-2 Algorithm with and Without Using Artificial Neural Networks." World Journal of Science and Technology - 1(12), 2011, pp.12-20

[76] RSA Algorithm - Java Implementation, www.cs.duke.edu/courses/summer04/cps001/lectures/Lecture16.ppt

[77] Khan Farhan Rafat and M. Sher, Novel Perspective for XML Steganography, Accepted and under publication in International Journal of Networks and Security (IJNS), Published by Recent Research Publication.

[78] Popa, R., An Analysis of Steganographic Techniques. The Politehnica University of Timisoara, Faculty of Automatics and Computers, Department of Computer Science and Software Engineering, 1998.

[79] J.Z Llner, H. Federrath, H. Klimant, A. Pfitzmann, R. Piotraschke, A. Westfeld, G.Wicke, G.Wolf. Modeling the security of steganographic systems, Proc. 2nd Workshop on Information Hiding, pp. 345-355, LNCS 1525, Springer-Verlag, Portland, 1998.

[80] Z. Wang, A. C. Bovik, H. R. Sheikh and E. P. Simoncelli, "Image quality assessment: From error visibility to structural similarity," IEEE Transactions on Image Processing, vol. 13, no. 4, pp. 600-612, Apr. 2004.

[81] Zhou Wang, Alan C. Bovik, Hamid R. Sheikh and Eero P. Simoncelli, The SSIM Index for Image Quality Assessment, http://www.cns.nyu.edu/~lcv/ssim/#usage

[82] MiniTab 16

[83] NSA surveillance: A guide to staying secure, http://www.theguardian.com/world/2013/sep/05/nsa-how-to-remain-secure-surveillance

Numerical Solutions of Heat and Mass Transfer with the First Kind Boundary and Initial Conditions in Capillary Porous Cylinder Using Programmable Graphics Hardware

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***Abstract*—Recently, heat and mass transfer simulation is more and more important in various engineering fields. In order to analyze how heat and mass transfer in a thermal environment, heat and mass transfer simulation is needed. However, it is too much time-consuming to obtain numerical solutions to heat and mass transfer equations. Therefore, in this paper, one of acceleration techniques developed in the graphics community that exploits a graphics processing unit (GPU) is applied to the numerical solutions of heat and mass transfer equations. The nVidia Compute Unified Device Architecture (CUDA) programming model provides a straightforward means of describing inherently parallel computations. This paper improves the performance of solving heat and mass transfer equations over capillary porous cylinder with the first boundary and initial conditions numerically running on GPU. Heat and mass transfer simulation using the novel CUDA platform on nVidia Quadro FX 4800 is implemented. Our experimental results clearly show that GPU can accurately perform heat and mass transfer simulation. GPU can significantly accelerate the performance with the maximum observed speedups 10 times. Therefore, the GPU is a good approach to accelerate the heat and mass transfer simulation.**

Keywords*—Genereal: Numerical Solution; Heat and Mass Transfer; General Purpose Graphics Processing Unit; CUDA

I. Introduction

During the last half century, many scientists and engineers working in Heat and Mass Transfer processes have put lots of efforts in finding solutions both analytically/numerically, and experimentally. To precisely analyze physical behaviors of heat and mass environment, to simulate several heat and mass transfer phenomena such as heat conduction, convection, and radiation are very important. A heat transfer simulation is accomplished by utilizing parallel computer resources to simulate such heat and mass transfer phenomena. With the helps from computer, initially the sequential solutions were found, and later when high-end computers became available, fast solutions were obtained to heat and mass transfer problems. However, the heat and mass transfer simulation requires much more computing resources than the other simulations. Therefore, acceleration of this simulation is very essential to implement a practical big data size heat and mass transfer simulation.

This paper utilizes the parallel computing power of GPUs to speedup the heat and mass transfer simulation. GPUs are very efficient considering theoretical peak floating-point operation rates [1]. Therefore, comparing with super-computer, GPUs is a powerful co-processor on a common PC which is ready to simulate a large-scale heat and mass transfer at a less resources. The GPU has several advantages over CPU architectures, such as highly parallel, computation intensive workloads, including higher bandwidth, higher floating-point throughput. The GPU can be an attractive alternative to clusters or super-computer in high performance computing areas.

CUDA [2] by nVidia already proved its effort to develop both programming and memory models. CUDA is a new parallel, C-like language programming Application program interface (API), which bypasses the rendering interface and avoids the difficulties from using GPGPU. Parallel computations are expressed as general-purpose, C-like language kernels operating in parallel over all the points in a application.

This paper develops the numerical solutions to Two-point Initial-Boundary Value Problems (TIBVP) of Heat and Mass with the first boundary and initial conditions in capillary porous cylinder. These problems can be found some applications in drying processes, space science, absorption of nutrients, transpiration cooling of space vehicles at re-entry phase, and many other scientific and engineering problems. Although some traditional approaches of parallel processing to the solutions of some of these problems have been investigated, no one seems to have explored the high performance computing solutions to heat and mass transfer problems with compact multi-processing capabilities of GPU, which integrates multi-processors on a chip. With the advantages of this compact technology, we developed algorithms to find the solution of TIBVP with the first boundary and initial conditions and compare with some existing solutions to the same problems. All of our experimental results show significant performance speedups. The maximum observed speedups are about 10 times.

The rest of the paper is organized as follow: Section II briefly introduces some closely related work; Section III describes the basic information on GPU and CUDA; Section IV presents the mathematical model of heat and mass transfer and numerical solutions to heat and mass transfer equations; Section V presents our experimental results; And Section VI concludes this paper and give some possible future work directions.

II. Related Work

The simulation of heat and mass transfer has been a very hot topic for many years. And there is lots of work related to this field, such as fluid and air flow simulation. We just refer to some most recent work close to this field here.

Soviet Union was in the fore-front for exploring the coupled Heat and Mass Transfer in Porous media, and major advances were made at Heat and Mass Transfer Institute at Minsk, BSSR. Later England and India took the lead and made further contributions for analytical and numerical solutions to certain problems. Narang [4-9] explored the wavelet solutions to heat and mass transfer equations and Ambethkar [10] explored the numerical solutions to some of these problems.

Krüger et al. [11] computed the basic linear algebra problems with the feathers of programmability of fragments on GPU, and further computed the 2D wavelets equations and NSEs on GPU. Bolz et al. [12] matched the sparse matrix into textures on GPU, and utilized the multigrid method to solve the fluid problem. In the meantime, Goodnight et al. [13] used the multigrid method to solve the boundary value problems on GPU. Harris [14, 15] solved the PDEs of dynamic fluid motion to get cloud animation.

GPU is also used to solve other kinds of PDEs by other researchers. Kim et al. [16] solved the crystal formation equations on GPU. Lefohn et al. [17] matched the level-set iso surface data into a dynamic sparse texture format. Another creative usage was to pack the information of the next active tiles into a vector message, which was used to control the vertices and texture coordinates needed to send from CPU to GPU. To learn more applications about general-purpose computations GPU, more information can be found from here [18].

III. An Overview of CUDA Architecture

The GPU that we have used in our implementations is nVidia’s Quadro FX 4800, which is DirectX 10 compliant. Quadro FX 4800 is one of nVidia’s fastest processors that support the CUDA API. All CUDA compatible devices support 64-bit integer processing. An important consideration for GPU performance is its level of occupancy. Occupancy refers to the number of threads available for execution at any one time. It is normally desirable to have a high level of occupancy as it facilitates the hiding of memory latency.

The GPU memory architecture is shown in figure 1.

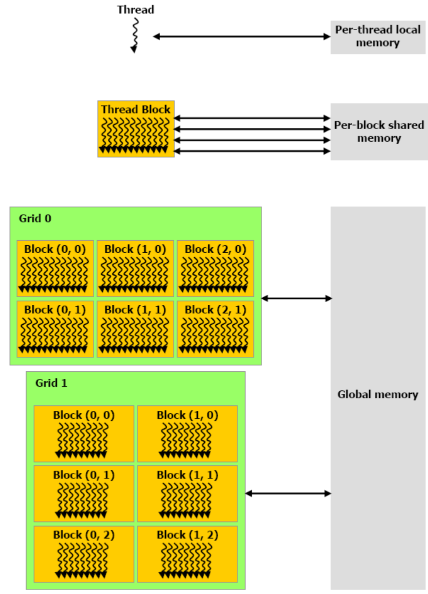

Fig. 1. GPU Memory Architecture [2]

IV. Mathematical Model and Numerical Solutions of Heat and Mass Transfer

A. Mathematical Model

Considering the Heat and Mass Transfer through a porous cylinder with boundary conditions of the first kind, let the z-axis be directed upward along the cylinder and the r-axis radius of the cylinder. Let u and v be the velocity components along the z- and r- axes respectively. Then the heat and mass transfer equations in the Boussinesq's approximation are:

$$\frac{\partial T}{\partial t} = k_1 \left(\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r} + \frac{\partial^2 T}{\partial z^2}\right) + k_2 \left(\frac{\partial C}{\partial t}\right) \tag{1}$$

$$\frac{\partial C}{\partial t} = k_3 \left(\frac{\partial^2 C}{\partial r^2} + \frac{1}{r}\frac{\partial C}{\partial r} + \frac{\partial^2 C}{\partial z^2}\right) + k_4 \left(\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r} + \frac{\partial^2 T}{\partial z^2}\right) \tag{2}$$

A prescribed constant temperature and concentration supplied by the hot plate at the left end $X=0$ of the cylinder, the initial and boundary conditions of the problem are:

$$r > 0, z = 0, t \le 0 \tag{3}$$

$$T(r,z,t) = T_0 \ , \ C(r,z,t) = C_0$$

$$r = a, 0 < z < \infty, t > 0 \tag{4}$$

$$T(r,z,t) = T_a + \varepsilon(T_a - T_\infty)$$

$$C(r,z,t) = C_a + \varepsilon(C_a - C_\infty)$$

$$r > 0, z \to \infty, t > 0 \tag{5}$$

$$T(r,\infty,t) \to T_\infty$$

$$C(r,\infty,t) \to C_\infty$$

Since the cylinder is assumed to be porous, μ_1 is the velocity of the fluid, T_p the temperature of the fluid near the cylinder, T_∞ the temperature of the fluid far away from the cylinder, C_p the concentration near the cylinder, C_∞ the concentration far away from the cylinder, g the acceleration due to gravity, β the coefficient of volume expansion for heat transfer, β' the coefficient of volume expansion for concentration, ν the kinematic viscosity, σ the scalar electrical conductivity, ω the frequency of oscillation, k the thermal conductivity.

From Equation (1) we observe that v_1 is independent of space co-ordinates and may be taken as constant. We define the following non-dimensional variables and parameters.

$$t = \frac{t_1 V_0^2}{4\nu}, z = \frac{V_0 z_1}{4\nu} \tag{8}$$

$$u = \frac{u_1}{V_0}, T = \frac{T_1 - T_\infty}{T_P - T_\infty}, C = \frac{C_1 - C_\infty}{C_P - C_\infty}, P_r = \frac{\nu}{k}, S_c = \frac{\nu}{D'}$$

$$M = \frac{\sigma B_0^2 \nu}{\rho V_0^2}, G_r = \frac{\nu g \beta (T_P - T_\infty)}{V_0^3}$$

$$G_m = \frac{\nu g \beta' (C_P - C_\infty)}{V_0^3}, \omega = \frac{4\nu\omega_i}{V_0^2}$$

When taking into account Equations (5), (6), (7), and (8), equations (1) and (2) reduce to the following form:

$$\frac{\partial T}{\partial t} + \frac{\partial^2 T}{\partial r^2} - 4\frac{\partial C}{\partial t} + \frac{1}{r}\frac{\partial T}{\partial r} = \frac{4}{P_r}\frac{\partial^2 T}{\partial z^2} \tag{9}$$

$$\frac{\partial C}{\partial t} + \frac{\partial^2 C}{\partial r^2} - 4\frac{\partial T}{\partial t} + \frac{1}{r}\frac{\partial C}{\partial r} = \frac{4}{P_r}\frac{\partial^2 C}{\partial z^2} \tag{10}$$

with

$$t \le 0 \tag{11}$$
$$C(r,z,t) = 0,\ T(r,z,t) = T_0$$

$$t > 0 \tag{12}$$
$$\frac{\partial C(r,z,t)}{\partial z} + k\frac{\partial T(r,z,t)}{\partial z} = 0$$

$$t > 0 \tag{13}$$
$$T(r,\infty,t) = 0,\ C(r,\infty,t) = 1$$

B. Numerical Solutions

Here we sought a solution by finite difference technique of implicit type namely Crank-Nicolson implicit finite difference method which is always convergent and stable. This method has been used to solve Equations (9), and (10) subject to the conditions given by (11), (12) and (13). To obtain the difference equations, the region of the heat is divided into a gird or mesh of lines parallel to z and r axes. Solutions of difference equations are obtained at the intersection of these mesh lines called nodes. The values of the dependent variables T, and C at the nodal points along the plane $x = 0$ are given by $T(0,t)$ and $C(0,t)$ hence are known from the boundary conditions.

In the figure 2, Δz, Δr are constant mesh sizes along z and r directions respectively. We need an algorithm to find single values at next time level in terms of known values at an earlier time level. A forward difference approximation for the first order partial derivatives of T and C. And a central difference approximation for the second order partial derivative of T and C are used. On introducing finite difference approximations for:

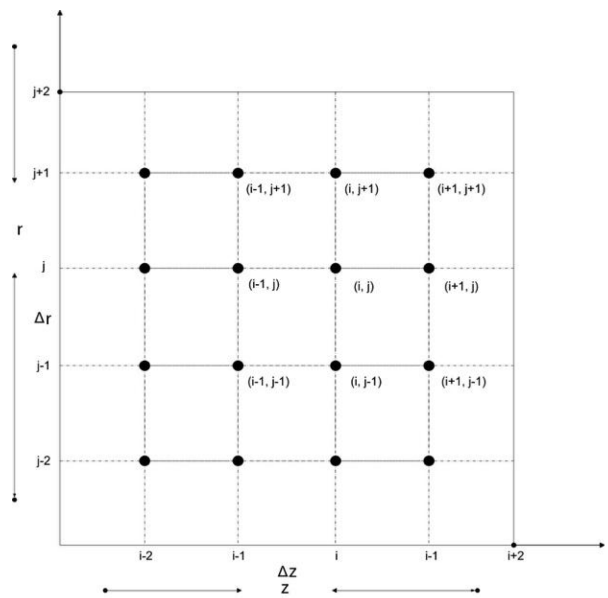

Fig. 2. Finite Difference Grid

$$\left(\frac{\partial^2 T}{\partial z^2}\right)_{i,j} = \frac{T_{i+1,j} - T_{i-1,j} + T_{i+1,j+1} - T_{i-1,j+1} - 2T_{i,j}}{2(\Delta z)^2}$$

$$\left(\frac{\partial^2 T}{\partial r^2}\right)_{i,j} = \frac{T_{i+1,j} - T_{i-1,j} + T_{i+1,j+1} - T_{i-1,j+1} - 2T_{i,j}}{2(\Delta r)^2}$$

$$\left(\frac{\partial T}{\partial r}\right)_{i,j} = \frac{T_{i+1,j} - T_{i-1,j} + T_{i+1,j+1} - T_{i-1,j+1}}{4(\Delta r)}$$

$$\left(\frac{\partial T}{\partial t}\right)_{i,j} = \frac{T_{i,j+1} - T_{i,j}}{\Delta t}, \left(\frac{\partial C}{\partial t}\right)_{i,j} = \frac{C_{i,j+1} - C_{i,j}}{\Delta t}, \left(\frac{\partial u}{\partial t}\right)_{i,j} = \frac{u_{i,j+1} - u_{i,j}}{\Delta t}$$

$$\left(\frac{\partial C}{\partial t}\right)_{i,j} = \frac{C_{i+1,j} - C_{i-1,j} + C_{i+1,j+1} - C_{i-1,j+1}}{4(\Delta t)}$$

$$\left(\frac{\partial^2 C}{\partial z^2}\right)_{i,j} = \frac{C_{i+1,j} - C_{i-1,j} + C_{i+1,j+1} - C_{i-1,j+1} - 2C_{i,j}}{2(\Delta z)^2}$$

$$\left(\frac{\partial^2 C}{\partial r^2}\right)_{i,j} = \frac{C_{i+1,j} - C_{i-1,j} + C_{i+1,j+1} - C_{i-1,j+1}}{2(\Delta r)^2}$$

$$\left(\frac{\partial C}{\partial r}\right)_{i,j} = \frac{C_{i+1,j} - C_{i-1,j} + C_{i+1,j+1} - C_{i-1,j+1}}{4(\Delta r)} \quad (14)$$

The finite difference approximation of Equations (9) and (10) are obtained with substituting Equation (14) into Equations (9) and (10) and multiplying both sides by Δt and after simplifying, we let $\frac{\Delta t}{(\Delta z)^2} = r' = 1$ (method is always stable and convergent), under this condition the above equations can be written as:

$$\frac{\partial C}{\partial t} = \frac{1}{2}\left(\frac{U + V - 2(T_{i,j} + C_{i,j})}{(\Delta r)^2} + \frac{U+V}{2r(\Delta r)} + \frac{U + V - 2(T_{i,j} + C_{i,j})}{(\Delta z)^2}\right)$$

$$\frac{\partial T}{\partial t} = \frac{1}{2}\left(\frac{2U + V - 2(2T_{i,j} + C_{i,j})}{(\Delta r)^2} + \frac{2U+V}{2r(\Delta r)} + \frac{2U + V - 2(2T_{i,j} + C_{i,j})}{(\Delta z)^2}\right)$$

Let U = $T_{i+1,j} - T_{i-1,j} + T_{i+1,j+1} - T_{i-1,j+1}$

Let V = $C_{i+1,j} - C_{i-1,j} + C_{i+1,j+1} - C_{i-1,j+1}$

(15)

V. EXPERIMENTAL RESULTS AND DISCUSSION

A. Experiments Setup and Device Configuration

The experiment was executed using the CUDA Runtime Library, Quadro FX 4800 graphics card, Intel Core 2 Duo. The programming interface used was Visual Studio.

The experiments were performed using a 64-bit Lenovo ThinkStation D20 with an Intel Xeon CPU E5520 with processor speed of 2.27 GHZ and physical RAM of 4.00GB. The Graphics Processing Unit (GPU) used was an NVIDIA Quadro FX 4800 with the following specifications:

CUDA Driver Version:	3.0
Total amount of global memory:	1.59 Gbytes
Number of multiprocessors:	24
Number of cores:	92
Total amount of constant memory:	65536 bytes
Total amount of shared memory per block:	16384 bytes
Total number of registers available per block:	16384
Maximum number of threads per block:	512

Banwitdh:

Host to Device Bandwith: 3412.1 (MB/s)
Device to Host Bandwith: 3189.4 (MB/s)
Device to Device Bandwitdh: 57509.6 (MB/s)

In the experiments, we considered solving heat and mass transfer differential equations in capillary porous cylinder with boundary conditions of the first kind using numerical methods. Our main purpose here was to obtain numerical solutions for Temperature T, and concentration C distributions across the various points in a cylinder as heat and mass are transferred from one end of the cylinder to the other. For our experiment, we compared the similarity of the CPU and GPU results. We also compared the performance of the CPU and GPU in terms of processing times of these results.

In the experimental setup, we are given the initial temperature T_0 and concentration C_0 at point $z = 0$ on the cylinder. Also, there is a constant temperature and concentration N_0 constantly working the surface of the cylinder. The temperature at the other end of the cylinder where $z = \infty$ is assumed to be ambient temperature (assumed to be zero). Also, the concentration at the other end of the cylinder where $z = \infty$ is assumed to be negligible (≈ 0). Our initial problem was to derive the temperature T_1 and concentration C_1 associated with the initial temperature and concentration respectively. We did this by employing the finite difference technique. Hence, we obtained total initial temperature of ($T_0 + T_1$) and total initial concentration of ($C_0 + C_1$) at $z = 0$. These total initial conditions were then used to perform calculations.

For the purpose of implementation, we assumed a fixed length of the cylinder and varied the number of nodal points N to be determined in the cylinder. Since N is inversely proportional to the step size Δz, increasing N decreases Δz and therefore more accurate results are obtained with larger values of N. For easy implementation in Visual Studio, we employed the Forward Euler Method (FEM) for forward calculation of the temperature and concentration distributions at each nodal point in both the CPU and GPU. For a given array of size N, the nodal points are calculated iteratively until the values of temperature and concentration become stable. In this experiment, we performed the iteration for 10 different time steps. After the tenth step, the values of the temperature and concentration became stable and are recorded. We run the tests for several different values of N and Δz and the error between the GPU and CPU calculated results were increasingly smaller as N increased. Finally, our results were normalized in both the GPU and CPU.

B. Experimental Results

The normalized temperature and concentration distributions at various points in the cylinder are depicted in Table 1 and Table 2 respectively. We can immediately see that, at each point in the cylinder, the CPU and GPU computed results are similar. In addition, the value of temperature is highest and the value of concentration is lowest at the point on the cylinder where the heat resource and mass resource are constantly applied. As we move away from this point, the values of the temperature decrease and concentration increase. At a point near the designated end of the cylinder, the values of the temperature approach zero and concentration approach one.

TABLE I. COMPARISON OF GPU AND CPU RESULTS (TEMPRETURE)

Z	GPU Results	CPU Results
7.8125	0.7168200	0.7171380
15.625	0.4733200	0.4738370
29.688	0.1866360	0.1871560
37.5	0.1068210	0.1072190
45.313	0.0650000	0.0652630
53.125	0.0456260	0.0457780
60.938	0.0376480	0.0377230
68.75	0.0347130	0.0347410
76.563	0.0337520	0.0337460
82.813	0.0335110	0.0334780
89.063	0.0334490	0.0333820
96.875	0.0334700	0.0333450
104.69	0.0335350	0.0333360
129.69	0.0336110	0.0333110
143.75	0.0270770	0.0269850
148.44	0	0

TABLE II. COMPARISON OF GPU AND CPU RESULTS (CONCENTRATION)

Z	GPU Results	CPU Results
7.8125	0.0325340	0.0315470
15.625	0.0348650	0.0332590
29.688	0.0349480	0.0333340
37.5	0.0345700	0.0333350
45.313	0.0341530	0.0333370
53.125	0.0338190	0.0333490
60.938	0.0336310	0.0333970
68.75	0.0336650	0.0335800
76.563	0.0341850	0.0342040
82.813	0.0354750	0.0355770
89.063	0.0385750	0.0387820
96.875	0.0480930	0.0484810
104.69	0.0707950	0.0714130
129.69	0.3914950	0.3924260
143.75	0.8265960	0.8268820
148.44	1.0000000	1.0000000

Figure 3 Shows the temperature distribution in the cylinder with 4 different normalized radiuses

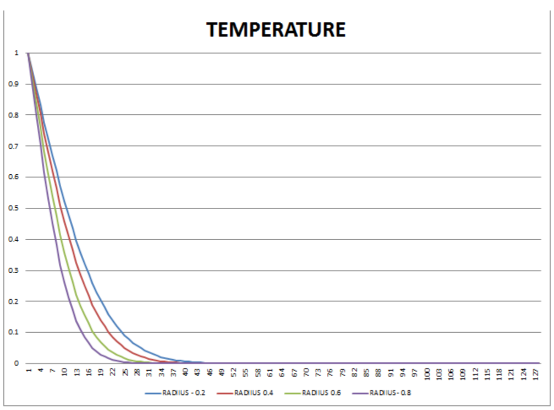

Fig. 3. Temperature Distribution in cylinder with different nomalized radiuses: r= 0.2, R=0.4, R=0.6, R=0.8

Figure 4 Shows the concentration distribution in the cylinder with 4 different radiuses

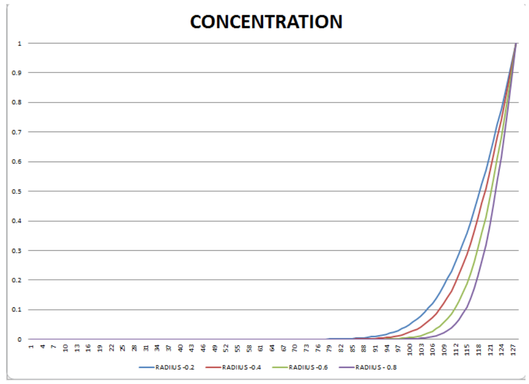

Fig. 4. Concentration Distribution in cylinder with different nomalized radiuses: r= 0.2, R=0.4, R=0.6, R=0.8

Furthermore, we also evaluated the performance of the GPU (nVIDIA Quadro FX 4800) in terms of solving heat and mass transfer equations by comparing its execution time to that of the CPU (Intel Xeon E5520).

For the purpose of measuring the execution time, the same functions were implemented in both the device (GPU) and the host (CPU), to initialize the temperature and concentration and to compute the numerical solutions. In this case, we measured the processing time for different values of N. The graph in Figure 5 depicts the performance of the GPU versus the CPU in terms of the processing time. We run the test for N running from 15 to 10000 and generally, the GPU performed the calculations a lot faster than the CPU.

- When N < 2500, the CPU performed faster than the GPU.
- When N > 2500 the GPU performance began to increase considerably

Figure 5 shows some of our experimental results.

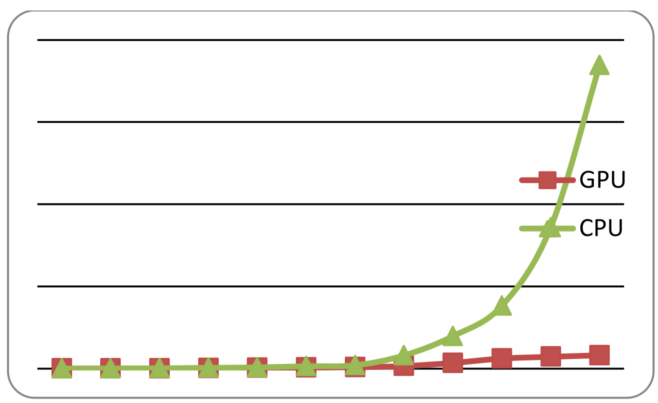

Fig. 5. Performance of GPU and CPU Implementations

Finally, the accuracy of our numerical solution was dependent on the number of iterations we performed in calculating each nodal point, where more iteration means more accurate results. In our experiment, we observed that after 9 or 10 iterations, the solution to the heat and mass equation at a given point became stable. For optimal performance, and to keep the number of iterations the same for both CPU and GPU, we used 10 iterations.

VI. Conclusion and Future Work

We have presented our work on the numerical solutions of the heat and mass transfer equations with the first kind of boundary and initial conditions using finite difference method on GPGPUs. We implemented numerical solutions to heat and mass transfer equations by using GPGPU on nVidia CUDA. We have demonstrated GPU can perform significantly faster than CPU in the field of mass caculations. Our experimental results also indicate that our GPU-based implementation offers a significant faster over CPU-based implementation and the maximum observed speedups are about 10 times.

There are several directions for future work. We would like to test our implantations on new generation GPUs and explore the new performance improvements offered by newer generations of GPUs. It would also be interesting to run more experiments with big data set. Finally, further attempts will be made to explore more complicated problems such as different boundary conditions and hollow cylinder geometry.

References

[1] J.D. Owens, D. Luebke, N. Govindaraju, M. Harris, J. Krger, A.E. Lefohn, T.J. Purcell,: A survey of general-purpose computation on graphics hardware. Computer Graphics Forum 26(1) (2007) 80-113.

[2] NVIDIA Corporation. NVIDIA Programming Guide 2.3. Retrieved July, 2009. www.nvidia.com.

[3] A. V. Luikov. Heat and Mass Transfer in Capillary Porous Bodies, Pergamon Press, 1966.

[4] Hira Narang and Rajiv Nekkanti. Wavelet-based Solution to Time-dependent Two-point Initial Boundary Value Problems with Non-Periodic Boundary Conditions, Proceedings of the IATED International Conference Signal Processing, Pattern Recognition & Applications July 3-6 2001, Rhodes, Greece.

[5] Hira Narang and Rajiv Nekkanti. Wavelet-based Solution of Boundary Value Problems involving Hyperbolic Equations, Proceedings from the IATED International Conference Signal Processing, Pattern Recognition & Applications June 25-26, 2002

[6] Hira Narang and Rajiv Nekkanti. Wavelet-based solutions to problems involving Parabolic Equations, Proceedings of the IATED International Conference Signal Processing, Pattern Recognition & Applications 2001, Greece.

[7] Hira Narang and Rajiv Nekkanti. Wavelet-Based Solution to Elliptic Two-Point Boundary Value Problems with Non-Periodic Boundary Conditions, Proceedings from the WSEAS international conference in Signal, Speech, and Image processing Sept 25-28, 2002

[8] Hira Narang and Rajiv Nekkanti. Wavelet-Based Solution to Some Time-Dependent Two-Point Initial Boundary Value Problems with Non-Linear Non-Periodic Boundary Conditions, International Conference on Scientific computation and differential equations, SCICADE 2003, Trondheim, Norway, June 30. July 4, 2003.

[9] Hira Narang and Rajiv Nekkanti. Wavelet based Solution to Time-Dependent Two Point Initial Boundary Value Problems with Non-Periodic Boundary Conditions involving High Intensity Heat and Mass Transfer in Capillary Porous Bodies, IATED International Conference proceedings, Gainesville, FL 2004.

[10] Vishwavidyalaya Ambethkar. Numerical Solutions of Heat and Mass Transfer Effects of an Unsteady MHD Free Conective Flow Past an Iffinite Vertical Plate With Constant Suction. Journal of Naval Architecture and Marine Engineering, pages 28-36, June, 2008.

[11] Jens Krüger and Rüdiger Westermann. Linear Algebra Operators for GPU Implementation of Numerical Algorithms. ACM Transactions on Graphics (Proceedings of SIGGRAPH), pages908-916, July 2003.

[12] Jeff Bolz, Ian Farmer, Eitan Grinspun and Peter Schröoder. Sparse Matrix Solvers on the GPU: Conjugate Gradients and Multigrid. ACM Transactions on Graphics (Proceedings of SIGGRAPH), pages917-924, July 2003.

[13] Nolan Goodnight, Cliff Woolley, David Luebke and Greg Humphreys. A Multigrid Solver for Boundary Value Problems Using Programmable Graphics Hardware. In Proceeding of Graphics Hardware, pages 102-111, July 2003.

[14] Mark Harris, William Baxter, Thorsten Scheuermann and Anselmo Lastra. Simulation of Cloud Dynamics on Graphics Hardware. In Proceedings of Graphics Hardware, pages 92-101, July 2003.

[15] Mark Harris. Real-Time Cloud Simulation and Rendering. PhD thesis, 2003.

[16] Theodore Kim and Ming Lin. Visual Simulation of Ice Crystal Growth. In Proceedings of SIGGRAPH/Eurographics Symposium on Computer Amination, pages 86-97, July 2003.

[17] Aaron Lefohn, Joe Kniss, Charles Hansen and Ross Whitaker. Interactive Deformation and Visualization of Level Set Surfaces Using Graphics Hardware. In IEEE Visualization, pages 75-82, 2003.

[18] GPGPU website. http://www.gpgpu.org.

LNG Import Contract in the perspective of Associated Technical and Managerial Challenges for the Distribution Companies of Pakistan

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***Abstract*—Energy Managers and Government Office Holders in Pakistan are nowadays pondering over multiple options for the resolution of ongoing Energy crises in the country.**

LNG (Liquefied Natural Gas) import has been finalized for being the quickest remedy among all the available options. LNG (Liquefied Natural Gas) contract is at the verge to be implemented in Pakistan. However there are several factors that need to be addressed while implementing the project. In this paper, identification of the challenges affecting the optimized distribution of gas is presented. The sustainability of LNG (Liquefied Natural Gas) Project depends upon the successful running of the project without facing any financial crises arising from the gas distribution losses. The motive of this paper is the identification of the factors that are risk for the sustainability and successful running of LNG Import in Pakistan on long term basis. In association it is required to identify technical and managerial challenges for the gas distribution companies in distribution of LNG. Moreover recommendations are proposed for modification in existing infrastructure and governing policies related to gas distribution companies for logical success and long term sustainability of LNG import in Pakistan.

Keywords*—*LNG Import Contract; sustainable energy solution; UFG (Unaccounted for Gas) losses; Infrastructure and policy Amendments; Technical and Managerial Challenges

I. Introduction

LNG (Liquefied Natural Gas) Import Contract for Pakistan has been perceived by the Energy Managers of the day as the quickest possible and least objectionable solution in the perspective of internal and external pressures. The LNG import from Qatar has been finalized by the Energy planners of Pakistan. The options under discussion are ranging through IP (Iran-Pakistan) Gas Pipeline Project, TAPI (Turkmenistan, Afghanistan, Pakistan & India) Gas Pipeline Project, Qatar-Pakistan Undersea Pipeline/ LNG import from Qatar, Energy Sector Cooperation with China to USA's Cooperation in Energy Sector. The realistic approach is to consider the merits and de-merits of every project after critical analysis rather doing something in emotional or fearful state of affairs. Moreover wisdom is, to prioritize these projects in the short and long term plans for Resolution of Energy Problems. The time requires us to consider the sustainable Resolution of Energy Sector crises rather than short term whims. There is nothing worse than having no option. Therefore, every option should be perceived in a realistic manner in the preview of National Energy Requirements and consumption sectors.

Pakistani Government has taken the practical initiative on the import of LNG from Qatar which is the quickest possible solution available among the less controversial options. The first LNG ship has arrived at the Arabian Sea, where it was welcomed in country with criticism, confusion, hope and whims. The debate is still there going on, for finalization of decision regarding the probable end users and beneficiaries. The Government has started importing the LNG (Liquefied Natural Gas) but concrete analysis about the associated challenges for feasible distribution of fuel costlier than domestic natural gas seems unexplored by the decision makers. The LNG is costing three times higher than domestic gas as fuel. At present it is supposed to become the 10 % share holder in the total gas based energy sector of Pakistan but shall expand to fulfill the all the demand gap in future. The gas Energy infrastructure of Pakistan is based on the **monopoly/oligopoly** of SNGPL (Sui Northern Gas Pipelines Limited) and SSGC. Both are having the status of being sole players in their respective terrains within the Country. Both the gas companies are supplying gas through their pipeline structure and at the expense of pipeline losses ranging from 10% to 13 % which are referred to as UFG losses (Unaccounted for gas losses) [1], [2] & [3].

These UFG (Unaccounted for Gas) losses include operational & accounting losses. The Oil & Gas Regulatory Authority (OGRA) remains conflicting with the two distribution companies over the permissible percentage of losses called UFG benchmark. UFG Benchmark may be considered limiting line for allowed Gas Distribution losses.

Those Losses which are considered beyond the control of distribution companies are exempted of any imposed financial penalty as determined by the Regulatory. The Companies are complaining about their constraints in terms of choice of consumers, infrastructural flaws, unionized staff, old gas distribution networks and working capacity constraints. Therefore the LNG distribution by the same gas distribution company infrastructures and using their existing pipeline network is definitely having losses.

The question arises “Is the Pakistani Regulatory Authority (OGRA) ready to allow the losses for an imported LNG fuel which is much costlier as well?” The failure in successful Distribution of LNG among consumers would end up in Chaos for energy sector which is already gasping. The whole activity must be financially feasible for sustainable future of LNG import.

A change in policies and infrastructure of these companies is required else LNG dream may become nightmare without any effort. The aim of this paper is to identify the technical and managerial challenges, the associated risks in LNG distribution in existing structure of gas distribution companies. It includes analysis of risks which may **jeopardize** the LNG solution for national energy Sector of Pakistan.

II. LNG Import & its Distribution

The LNG import planned by the national decision makers is either to test their efforts in helping the gasping energy sector, or to build their good reputation for efforts in resolution of Energy crises. Initially the LNG sale was offered to IPPs (Independent Power Producers; private electrical power producing companies) and fertilizers i.e. the corporate clients. But the Sale of LNG being costlier than the Country’s own natural gas had received a varying response from the corporate Corners. Some consumers have accepted the offer in preview of current gas load curtailments and gas load shedding. But on the other hand some consumers have rejected the proposal for being costlier fuel than natural gas and furnace Oil. CNG Sector which was facing severe gas curtailment crises in the ongoing perspective of gas load management, have shown their interest in purchasing LNG from SNGPL specifically in the areas of Punjab and Islamabad.

Since LNG is there and LNG import Stakeholders has to decide the ultimate category of consumers for being the end user of LNG, various options are under consideration. CNG Association is using all of its probable channels for being the most suitable candidate. However Government can’t afford to financially loose this project. The distribution companies were also not willing to accept the liability of associated losses. The companies know their capability and the condition of their pipeline networks therefore are reluctant to use their distribution network for the Costlier LNG fuel after degasification (R-LNG). If this happens then the accounts of the companies listed on the stock exchange would definitely have to face bearish trend. The distribution companies can’t afford the liability of losses for LNG. These gas companies are already under litigation with OGRA on the Legal forums for revision of Bench Mark of UFG losses and penalty imposed on losses by the Regulatory.

The **LNG importers** has not worked out any other option for LNG infrastructure but has opted for using the existing gas network of the distribution companies. The Companies were initially reluctant for the LNG sale to every consumer with exception to the corporate clients where at the end of Transmission network SMS cum CMS (SMS; Sales Metering Station. Where gas is measured and passed for sale in distribution network. CMS; Consumer Metering Station. Where gas is measured and passed for consumption by consumer) can deliver the gas while avoiding the fuss of distribution network losses.

The distribution network is a giant interconnected structure of pipelines which is approximately 95000 KM for SNGPL and having consumer of every category located on it. Control over the distribution network depends upon multiple factors ranging from controllable to uncontrollable aspects.

For selling LNG to CNG Stations it has to be transported in the distribution network. These CNG Stations are located in every hook and corner of the metropolitan cities and highways having no initial planning for standard minimum distance. The CNG stations are located on the same distribution network which is gasping with low pressures having consumers of every category located on the same pipeline network. LNG would just get lost in the black holes of the distribution pipelines network and scenario won’t change.

No one is willing to bear the financial liability of the associated gas distribution network losses. These results from reasons including poor workmanship in developmental activity, politically altered Engineering Designs of pipeline networks, and capacity constraints to cater the operational load while maintaining the good standards. SNGPL is greater in network size and infrastructure than the SSGC, therefore may be used as reference from now onwards to discuss the distribution company.

However in the most recent development SNGPL and SSGC have agreed for distribution of LNG after hot debate on the corporate arena. Though initially it is being carried out on limited scale but have a future extension plan of this project on larger scale. The LNG dedicated line laying process is under progress for SNGPL. At present SSGC is feeding its system with Re-gasified LNG imported on the shore and leaving the domestic gas share as swap for SNGPL as temporary arrangement till construction of dedicated pipeline for Re-gasified LNG. There is difference in the calorific values of the domestic natural gas and LNG. SNGPL has selected from existing consumers for LNG which are non-defaulters and willing to accept the terms and conditions.

III. Brief Review of LNG Import Contract [4-8]

Pakistan State Oil (PSO) has been mandated by Government of Pakistan for LNG purchase. Three LNG import options were being considered by Government of Pakistan which are:

1) *Government to Government basis with Qatar.*

2) *Through international open tendering process.*

3) *through spot purchase from pre-qualified suppliers.*

As per LNG transaction structure, PSO will import LNG and SNGPL and SSGC will purchase their notified shares (2/3 - SNGPL & 1/3 - SSGC) of LNG from PSO. These companies would onward sale it to their respective customers. This will be done through an agreement between PSO, SNGPL and SSGC. LNG re-gasification facility would be required at Karachi port. ENGRO ELENGY (A Pakistani private limited company) will provide LNG re-gasification services at Port Qasim. LNG Services Agreement (LSA) was signed between SSGC and ENGRO ELENGY Terminal Private Ltd (EETPL) on 30th April, 2014, for storage and re-gasification of LNG. EETPL will use Floating Storage & Re-gasification Unit (FSRU) to convert LNG into vapor phase.

SALIENT FEATURES OF EETPL & SSGC LNG SERVICE AGREEMENT (LSA)

The first gas consignment was due on 30th March 2015, with terms of agreement for fifteen years. The scope of Engro Elengy Terminal Private limited EETPL is comprising of the responsibility of Jetty and other marine structures, Dredging of terminal basin, Floating Storage and re-gasification unit (FSRU) and connecting pipeline up to SSGC Network.

MAJOR PROJECT COMPONENTS

- ✓ LNG SUPPLY
- ✓ RE-GASIFICATION
- ✓ GAS DISTRIBUTION

Volume for First year import would be 200 MMCFD (1.5 MTPA LNG) and VOLUME for second year to fifteenth year import would be 400 MMCFD (3 MTPA LNG). It means it would be 10% of the current 4 BCF gas available in country. LNG Allocation for SNGPL is 2/3rd and for SSGC is 1/3rd. Imported LNG is planned to replace expensive liquid fuel in power sector.

SSGC has invited bids from the interested parties to provide LNG Storage and Re-gasification Services by construction of 2nd LNG Terminal at Port Qasim. For this purpose a tender has been floated in **Oct, 2014.** The terminal capacity is 400 to 500 MMCFD with fifteen years of contract term. The Bid submission date was 15th JAN 2015 and allowed period for first gas supply was set for maximum of 24 months from execution of LSA (LNG Services Agreement).

The above facts and figures are based on the initial work plan.

However later on LNG Project had to incorporate changes arising from the criticism, opposition and proposals. The demand of CNG Association to be a partner in the business of LNG import by development of Universal Gas development company (UGDC) was also a basis of present changes.

UGDC was not having gas pipeline infrastructure. Moreover due to solid realities that it was not granted NOC (No Objection Certificate) from OGRA and Ministry. UGDC had the plan to pay traffic charges to SNGPL for carrying R-LNG through its distribution network but nobody was willing to bear the UFG losses during transportation.

For the distribution companies the traffic charges are meaningless in the face of UFG losses during transportation. The two Companies were not willing to undertake the liability of losses as they already pleaded their case of UFG Benchmark in Courts and Council of Common Interests to secure their eroding profitability. In this scenario an additional liability of transporting a costlier fuel for some other new competitor is really a great risk for the company businesses.

However it was considered appropriate to acquire project insurance and leave this responsibility on the shoulders of two existing gas companies i.e. SNGPL and SSGC rather than allowing any new player for LNG distribution due to infrastructure constraints and timeline requirements.

However long term success, is realistically based on the infrastructure and policy amendments for sustainable results of LNG import Project without damaging any stakeholder.

IV. OGRA'S (OIL & GAS REGULATORY AUTHORITY) DEFINED CONSUMER CATEGORIES FOR THE GAS DISTRIBUTION COMPANIES AND CHOICE OF FAVORITE CONSUMER FROM BUSINESS PERSPECTIVE

The OGRA has defined the following major four classifications of consumer categories from operational and tariff perspectives. [9]

1) *Industrial Consumers*
2) *Commercial Consumers*
3) *Domestic Consumers*
4) *Special Domestic/ Bulk Consumers.*

The further detailed categories of the consumers as per OGRA are:

I. Domestic Sector / Special Domestic (i.e. Charitable organizations and Government Sector)
II. Commercial
III. Special Commercial (Roti Tandoors)
IV. Ice Factories
V. Industrial
VI. Compressed Natural Gas (CNG) Stations
VII. Cement
VIII. Fertilizer Companies
IX. Power Stations (WAPDA's and KESC's Power Stations)
X. Independent Power Producers
XI. Captive Power**.**

The above categories of consumers can further be classified based on the gas quantity required by consumers and business nature as per gas sales contract which are

(A) Corporate Consumer (Power, Fertilizers & Cement)
(B) Bulk Consumers (Industry, Bulk Commercial & Bulk Domestic)
(C) Retail Consumers

Gas Distribution companies always prefer Corporate Consumers for their business. Corporate Consumers are better as they require less hectic operational efforts and also probability of pilferage/losses is low. They can be monitored easily for comparatively much larger volume of gas than other small retail consumers. The Bulk consumer is ranked second favorable consumer and the retail consumer is the least favorable consumer from business point of view for gas distribution companies. It is similar to the fact that the measurement errors though very small multiplied by a large number of consumers produce an inevitable percentage of loss. An unrealistic number of resources are required for rectification of such no. of measurement errors of equipment if ever possible.

Total loss=L (Loss for every individual gas consumer) x N (Total Number of consumers)

Therefore the corporate and bulk consumers being small in number are comparatively easier to manage from operational perspective. The retail consumers being large in number are difficult to manage within limited resources.

Moreover, the cost-benefit analysis of the gas consumers also justifies this fact that Corporate and bulk consumers justifies better cost benefit advantage in comparison to the retail gas consumers which are also enjoying subsidy in billing tariff.

V. UFG & Losses in the Network of SNGPL

Unaccounted for Gas (UFG) can be defined as the difference between the total volumetric amount of gas available for sale to a transmission or distribution system and volumetric amount of gas billed & sold.

Formula for calculating % age UFG losses:

$$\text{UFG (\%) losses} = \frac{\text{Gas available for Sale} - \text{Metered Gas Sold}}{\text{Gas available for Sale}} \times 100$$

The UFG losses can be further categorized into following two types: [10]

1) Operational losses

2) Accounting losses

(a) Operational Aspect of Unaccounted for Gas losses

Operational UFG losses include the following categories

a. Gas Network Leakages
b. Measurement Errors in metering Gadget
c. Gas Pressure Regulations
d. Third Party Damages for Gas pipeline network
e. Construction Activity in the area where underground gas infrastructure is present
f. Theft of gas by Pilferers

(b) Accounting Aspect of Unaccounted for Gas losses

Accounting UFG losses include the following categories

a. Gas Contractual errors
b. Data Entry errors in the database of Customer Care & Billing (CC&B)
c. Cycle Billing errors
d. Report Compilation errors
e. Chart Integration errors
f. Pending Punching of new activities in CC&B sytem database.

SNGPL's Network losses can be specifically summarized in the fig 1:

VI. Factors Contributing to UFG Losses in SNGPL

There are multiple factors contributing to UFG losses in the network of SNGPL which can be further categorized as controllable, semi-controllable and uncontrollable. [11] and [12]

Controllable Factors:

- ❑ Poor workmanship
- ❑ Quality of material
- ❑ Leakages in new and rectified gas connections
- ❑ Measurement errors
- ❑ Billing errors
- ❑ Gas Network Rehabilitation i.e. Very old / leaking distribution network and budgetary constraints to replace the identified network
- ❑ Accounting Errors

Semi-Controllable Factors:

- ❑ Third party damages
- ❑ New EVC (Electronic Volume Corrector) tampering techniques being adopted by gas pilferers (use of magnets to retard the magnetically coupled driving dock/dog of mechanical counter of Industrial gas meters etc.)
- ❑ Theft of gas where slight public resistance is faced

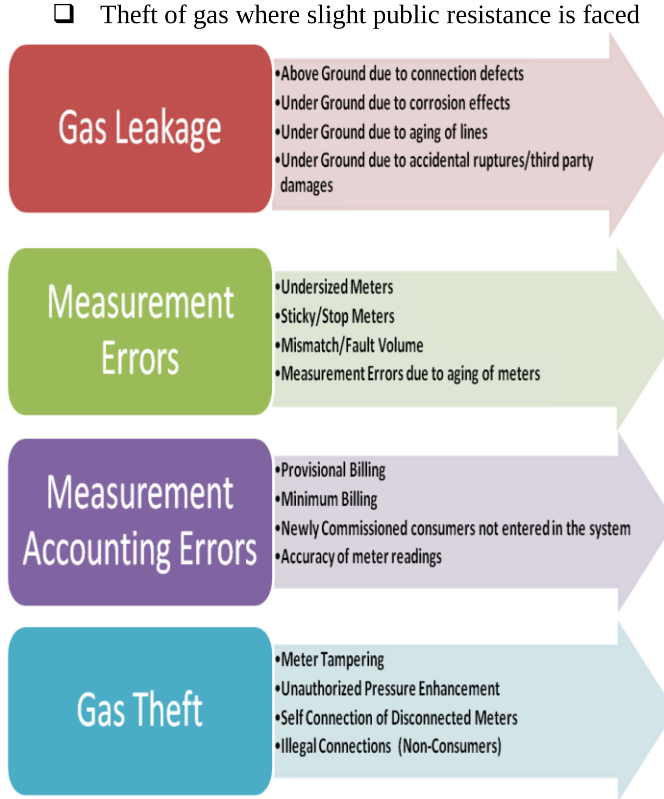

Fig. 1. Summarized Reasons for UFG Losses

Un-Controllable Factors:

- Shift of gas from Bulk to Retail sector consumers. Losses in bulk sector are minimal and vice versa.
- Continuous extension of distribution network (Socio-political factors in Gas Network Development/extension).
- Gas theft by non consumers.
- Litigant gas pilferers and slow processing of cases at different legal forums. Cases pending in Courts.
- Losses in Law and Order affected, Gas producing Areas in Southern Districts of KPK Province.
- Non cooperative attitude of Police / Law Enforcing Agencies for control of Gas Theft.
- Paucity (slow pace) of annual gas connection targets compared with the gas applicants.
- Increased Gas Prices regulated by OGRA and the public having no dependable alternative regular fuel at national level for consumption.

Few of the factors as mentioned above are beyond the control of SNGPL. Therefore devising better policy can resolve these issues.

For example; Paucity in new gas connection provision arising from its low annual targets allocated compared to the total gas applications received, need to be addressed by devising a better policy.

VII. Financial Impact of UFG and Profit Erosion

The financial impact of UFG can be well understood by using a quick math calculation.

A Quick Math Calculation

- ✓ SNGPL Annual UFG = 68,837 MMCF (10.20%)
- ✓ SNGPL Per day UFG = 189 MMCFD
- ✓ Avg. Cost/MMCF = Rs 288,190

Financial Cost of Lost Gas (UFG)

- ✓ 68,837 (MMCF) x Rs 288,190 (Gas price)
  = Rs 19,838 Million

Such a huge amount from the national **exchequer** is lost annually due to the UFG losses.

(All above figures for FY-2011-12, declared by OGRA)

VIII. UFG Benchmarks & Disallowance by OGRA

OGRA is the regulatory body who monitors the distribution companies by setting of UFG Benchmarks as performance indicators of efficiency. OGRA disallows the losses beyond the Benchmarks by imposing penalty against the inefficiency. But SNGPL and SSGC remains at conflict with gas regulatory body on the Legal Forums in Courts. The controversial issue of **Benchmark** remains under discussion at significant forums of honourable Supreme Court and the Council of Common Interests Pakistan. However, the year wise tabulated details of UFG Benchmark and Disallowance by OGRA for SNGPL is elaborated in Table I. Moreover the eroding profitability is graphically depicted in Fig.2.

However after much deliberation on the issue of Benchmark, OGRA has agreed to appoint third party commercial Auditor for accurate determination of Benchmark of UFG losses keeping in view the realistic constraints and actual operating conditions of the Company. In order to accomplish the task M/s KPMG Taseer Hadi & Co Chartered Accountant firm has been appointed by OGRA.

TABLE I. UFG Benchmark and SNGPL's UFG Losses

Fiscal Year	UFG Benchmarks		Actual
FY	Lower	Upper	SNGPL
2003-04	6.50%	6.50%	6.65%
2004-05	6.00%	6.00%	6.86%
2005-06	5.70%	6.00%	6.61%
2006-07	5.40%	6.00%	7.77%
2007-08	5.10%	6.00%	8.04%
2008-09	4.80%	5.50%	8.05%
2009-10	4.50%	5.50%	9.63%
2010-11	4.25%	5.00%	11.21%
2011-12	4.00%	5.00%	10.20%

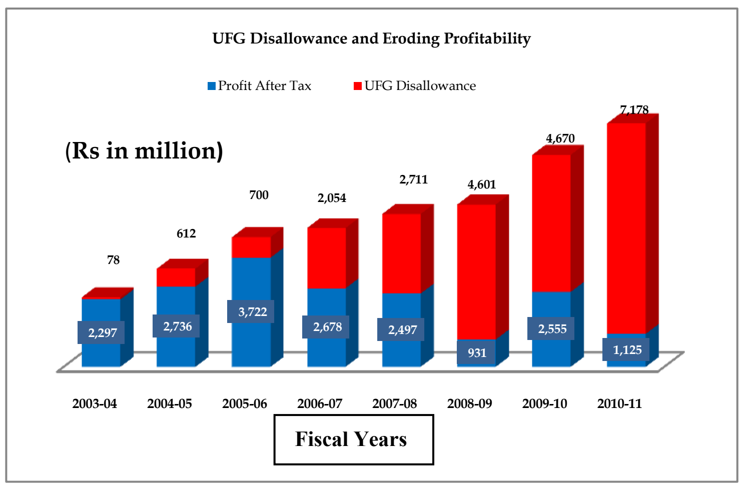

Fig. 2. UFG Disallowance and eroding profitability

IX. Managerial & Technical Challenges in LNG Distribution

LNG distribution while using the existing gas pipeline infrastructure of the SNGPL and SSGC is really risky and challenging.

The term SMS refers to Sales Metering Station; (SMS is first point, after transmission network of Gas pipelines from where Gas Sales can be executed to the consumers) where as CMS refers to Consumer metering Station; (CMS is the

Consumer metering station located on distribution network and gas is measured with gadget at this point for accurate billing to consumer as per actual consumptions in relevance to contractual pressures and Contractual Load Appliances).

SMS cum CMS refers to an assembly when there is no distribution pipeline network between an SMS and CMS meaning that the two stations are constructed having no physical distance between them. This Assembly is helpful in avoiding distribution network losses which is always very problematic due to its leakages, haphazard off-takes for consumers and its overloaded and low pressure conditions. The distribution network's life is low due to its compromised laying and constrained operating conditions.

One condition differentiating transmission and distribution networks is that the transmission network is laid after proper acquisition of right of way (ROW) land which is dedicated with almost no practical interference after its acquisition and it is also maintained by concerned transmission department. However distribution network is laid in the government land and passes along general public areas like along the roads and streets. No Right of Way abbreviated as ROW is dedicated for distribution pipelines and it is hence full of interference arising from surrounding infrastructure developments.

However SMS cum CMS infrastructure can only be used to supply gas to the corporate/large consumers which are located at the end point of transmission pipeline laid on the company's owned **right of way (ROW)** having negligible losses. But the use of distribution network where there is UFG due to the reasons as discussed earlier, LNG distribution dream can become a nightmare if the associated challenges are not addressed properly.

One of the options is to setup a separate infrastructure which is not financially feasible and a time consuming approach. The CNG Sector has been offered the provision of LNG for running of their businesses but since they are located on the distribution networks and gas passed to distribution network can be consumed by all the retail consumers as well which were actually not the intended clients for LNG. This fact is posing serious technical and managerial threats and challenges to the gas distribution companies and requires business process re-engineering for a feasible business.

These managerial & Technical challenges are:

1) Pressure Profiling for Leakages & Measurement Errors of undersized meters

SNGPL is doing the pressure profiling during peak and non-peak hours in preview of reduction of gas leakage losses at reduced pressures. But it is a harsh fact that when the network line pressures are reduced the Corrected flow rate capacity of the meters installed on the network is reduced at the decreased pressures and it introduces gas measurement errors in meters due to under sized capacity in relevance to load.

Therefore if pressures are reduced the leakage losses are reduced but the measurement losses due to undersized meters increases and if pressures are increased it increases the corrected capacity of meters at healthy line pressures but also increases the line losses via leakages**.**

It is really challenging and tough to manage the optimum balance between the two aspects due to existing network conditions.

2) BULK to RETAIL Volume RATIO in Sales

The Gas Allocation Policy of Pakistani Government gives top priority to retail sector, to facilitate the general public, where the percentage of gas losses are much higher than the Bulk sector. It is also not the feasible sale for distribution company for the high cost to low benefit ratio.

Moreover, in the past five Years, Gas Distribution Network of SNGPL has been extended by 27,844 KMs which depicts 46.44% increase in distribution network. Consequently 954,977 Nos. domestic consumers have been added resulting in 30.26% increase in retail consumers.

The unprecedented growth of new connections during last few years has adversely affected SNGPL bulk to retail ratio. It was 45:55 for Bulk to Retail in fiscal year FY 2003-04 but consequently reduced further to 22:78 in FY 2013-14.

- During 1998-99 to 2005-06 gas input increased by 115% which was mostly diverted to Bulk sector where UFG loss is minimal, which resulted in reduction of UFG percentage losses from 11.28% in fiscal year FY 1998-99 to 6.61% in FY 2005-06.
- From 2005-06 to 2011-12 the increase in gas input was only 10% whereas consumption in retail sector increased sharply from 369 BCF in 2005-06 to 517 BCF in 2011-12 i.e. 40.1% and Bulk consumption decreased from 244 BCF to 157 BCF i.e. 35.6% respectively in Bulk sector.
- Gas from bulk sector was diverted to retail sector from 40% sale in year 2005-06 to 22% sale in year 2013-14, thereby increasing the percentage UFG loss from 6.61% to 11.48%.

Therefore choice for adaption of specific Bulk to Retail Ratio in Sales is not available for gas Distribution companies. This is one of the major challenges for these companies.

3) Incorporation of Recovery based Theft Volume detected.

Company establishes the pilferage/theft volumes against the gas pilferers strictly in line with OGRA's Procedure of Dealing with Theft of Gas Cases. As per the prevailing practice, the volume allowed in gas sales is linked with recovery. Whenever theft volumes are charged to gas pilferers they manage to get relief from the courts in form of stay orders and thus the established theft volumes remain unrecovered till the decision of the case, which takes several years. The above criterion followed by OGRA is causing unbearable loss. The real Efforts of the company in identifying the theft cases and establishing the pilferage volumes do not yield the fruitful results for being recovery based volumes. The gas pilferers use the procedural hitches for their advantage.

It is a matter of fact that only approximately 60% of the theft amount booked is recovered whereas rest remains pending at litigation forums. Moreover, in large number of cases, consumers default to pay the booked charges thus resulting in non recovery of theft charges as well as accumulation of bad debts. The non-consumer theft recovery cases are even less than 1 % of total.

Therefore a lot of energy of company is invested on an aspect where there is hundred percentage risk of effort materialization. It is fruitful in case of some recovery to consider the theft volume incorporation while calculating UFG loss Percentage.

4) Human Resource

- (Unionized and politicized Subordinate Staff)

The Human Resource of these companies is categorized as

- ✓ Management/Executives (Top, Middle and Lower Management)
- ✓ Permanent Subordinate Staff
- ✓ Daily Wages / Casual Employees

The Permanent subordinate staff is having a political representative body known as labor union. The subordinate staff of the distribution companies is unionized and politicized human resource. Such a structure is always offering great resistance towards any change in policy for improvement of efficiency or work norms. The staff member which are hired on Blood Quota basis are often just a useless addition to the number count while maintaining the absenteeism or even worse by involvement in notorious activities for ulterior motives. These unionized and politicized human resources are headache for the management. Effective implementation of plans and policies is not possible with such staff members. The CBA (Collective Bargaining Agreement) representative body, also known as labor union, which is principally supposed to safeguard Staff's rights, have become contaminated bodies with political influence of sponsor employees. The funding for election campaign of these unions often comes from the subordinate employee corners which invest black money to yield a larger personal interest at later stages. Such type of staff is a permanent liability for the company and managing them is a major challenge.

The casual staff is also hired and is largest in number more than permanent staff employees and executives. Although there are many associated issues arising from their presence but most prominent effect is a large and rapid turnover in company. Therefore no consistent quality of work can be maintained for long.

The lower level executives are the immediate line managers who are supposed to first interact with these staff for work execution. The lower executives/first line managers often feel tensed as there is pressure from management to yield results and achieve targets but on the other hand the CBA and labor union are creating problems for them. This all staff alignment is a major challenge to achieve the desired level of work quality in order to avoid UFG losses.

Therefore challenge remains there to optimize the human resource efficiency while managing all these odds.

5) Over Riding Effects

Apart from the efforts being made by the Company, there are some overriding effects which are badly hampering SNGPL efforts. Some of such factors are as follows:

a) Electricity crisis

The prevailing electricity crisis in the country is also affecting the efficiency of Gas Company. It has not only affected the measurement accuracy in domestic sector but due to long lasting power shut downs network protection is not possible. This has rendered underground gas pipeline network unprotected, which has resultantly aggravated the underground leaks due to poor cathodic protection against corrosion.

A large number of domestic and commercial consumers are using gas fired electric generators to overcome the electricity crisis. This has undersized the low capacity domestic meters. Moreover fiddling with gas regulators and tampering with meters has become a common phenomenon. This is an **overriding effect for** Distribution losses.

b) Shortage of Gas

Due to shortage of gas and restrictions on new gas connections, the trend of unauthorized/illegal connections has increased manifold. Although Company is making a continuous effort in identifying and disconnecting illegal connections/networks, making the lives of field staff at risk but still some of the individuals backed by influential people succeeded in reconnecting the illegal networks time and again. The fast growing development network is yet another challenge that the Company is facing i.e. hampering SNGPL efforts against the gas losses.

a) Measurement inaccuracies due to low pressures in the System

The existing continuous low pressures in system has increased the tendency of meter defects due to wear and tear of internal parts because of increased velocity and travel of dust and gas condensate in meter body.

6) Capacity Constraints and over flexible HR Structure

The capacity building of the distribution company has not been on concrete grounds in the past. The HR structure is very flexible as per doctrine of necessity. The Job Descriptions and KPIs (Key Performance Indicators) are very flexible and there is no hard and fast rule for the transfers or job assignments.

Sometimes officer of a higher cadre from senior management is performing a job which later on, is assigned to another person from middle management. At times even officer from junior management is assigned with the same job descriptions and assignments. Although it is already under consideration by management but there is a lot of room for improvement.

Even the role of same department is not uniform and vary from Region to Region based on the personal preferences of the Managers. This has completely spoiled the capacity building of the company. Moreover it is a source of capacity constraint. There is no concrete professional level achievement by a specific department.

The executives and staff keep on switching within departments. Due to random shifts and transfers the work is seen to start from ab-initio in a Section by the advent of irrelevant new comers from other departments and the fresh inductions working without any supervision. This is a serious capacity gap and need assessment for betterment of the company affairs.

X. Conclusions

The LNG Import Contract is a good idea but the distribution of LNG using the same existing gas pipeline infrastructure of gas distribution companies (SNGPL & SSGC) in full length without any change in existing infrastructure or policies is definitely not feasible.

The existing structures of the gas distribution companies are having complicated problems ranging from poor operating Network conditions to Human Resource management Problems.

There are capacity constraints in gas Distribution companies for long term control on the gas network losses. Most of the times fire fighting is carried out to yield short span results.

Initially LNG distribution should be confined to Corporate Sectors only where the giant consumers are located at the end of transmission mains without involvement of distribution network. However a concrete re-structuring of infrastructure should be carried out by network segmentations before expansion of R-LNG distribution.

However the other consumers located on the distribution network of SNGPL or SSGC must be filtered properly and supplied with the LNG having dedicated pipelines.

If LNG is intended to benefit the other bulk and retail consumers located on distribution lines then another proposal is to dedicate an SMS on the transmission network of each Region and at that SMS R-LNG can be provisioned with the facility for filling it in cylinders after compression. This can eliminate the risk of UFG losses related to the distribution of costlier LNG fuel.

The policies for developmental activities must be made realistic in the light of Principles of Quality Management System Standards which requires “Factual Approach to Decision making”.

The companies should be encouraged to allow provision of new connections on fast track basis.

The activities which are provoking unnecessary litigation must be avoided. The cost benefit Analysis of the policies must be carried out by OGRA and shared with the decision makers in Ministry of Petroleum & Natural Resources Pakistan. This would ease out many operational constraints and help in capacity building of the energy distribution companies.

The realistic approach must be adapted for every project which is under consideration at any forum for solution of energy crisis in Pakistan along with infrastructure analysis of the existing distribution pipeline network. The realignment of infrastructure and policy modification is must for making an effective and successful plan for sustainable solution of Energy crises in Pakistan

XI. Recommendations

Recommendations for Combating these challenges are:

- ✓ The interconnected network should be isolated into proper segments/small pockets which are totally independent and reconciled by installation of check meters in the Central Database at the end of every monthly billing cycle.
- ✓ The company should be empowered to decide the choice of consumer for its R-LNG Sale.
- ✓ Network Rehabilitation should be a separate project and should be carried out independent of operational departments.
- ✓ The Decision making powers should be transferred to middle and lower level management for effective control and monitoring.
- ✓ The Standard operating procedures should be uniformly implemented across the different distribution Regions.
- ✓ The hierarchy and allocation of resources should be based on realistic workloads.
- ✓ The absenteeism among employees should be eliminated and those which are overburdened should be given realistic work.
- ✓ The de-centralization of Decision making and empowerment of Gas Distribution Regions should be carried out.
- ✓ All departments should be mobilized following the theme of Total Quality Management (TQM) Principles to streamline the company operations and processes.
- ✓ The interloping of gas network to address the winter low pressure complaints must be stopped and fluid dynamics study should be carried out. Then based on this study gas network modification and rectification should be carried out.
- ✓ Team building approach for productive working units of human resource should be promoted to harness the better results.

The company’s departmental managers and line managers should be taught the philosophy of TQM to control the business and operational processes in proficient manner. The approach for leaving the responsibility of controlling the UFG losses for a specific department must be discarded and every department and every person must control his share of poor workmanship to stop contributing to UFG losses. Before such measures company should confine to only pilot project distribution of R-LNG as it would bring bad debts to the business if done in the traditional way.

Only after adapting new sustainable approach the company should move to massive scale handling of LNG import Project.

XII. FUTURE WORK

This project can be extended to explore a feasible infrastructure for Energy Sector in the light of TQM (Total Quality Management) principles of ISO-9001. The TQM approach can be applied for quality energy infrastructure to avoid the associated challenges and avoid perspectives of failure while implementing new solutions for Energy Requirements. The Process Re-Engineering approach should be adapted in business traits to achieve sustainable results.

REFERENCES

[1] Arshad H. Abbasi, Maha Kamal. , "Importing Liquefied Natural Gas (LNG): A Policy Analysis"*Sustainable Development Policy Institute*.

[2] Muhammad Munir, Muhammad Ahsan, Saman Zulfqar, "Iran-Pakistan Gas Pipeline:Cost-Benefit Analysis", Journal of Political Studies, Vol. 20, Issue-2,2013,161:178.

[3] "LNG: The Whole Truth", The News Saturday May 02, 2015 Print Edition.

[4] Draft of Gas Sales Agreement (GSA)

[5] Draft of Joint Venture Agreement for the development of a liquefied Natural Gas Project.

[6] Draft of Petroleum Law

[7] Draft of Master Sales Agreement for the sale and purchase of liquefied natural gas spot cargos delivered on an ex-ship basis.

[8] Draft of LNG Terminal Use Agreement (Version 2)

[9] OGRA notification, Islamabad the 1st January, 2013, S.R.O. (I)/2012.- Insupersession of its notification No.S.R.O.1497(I)/2012, dated 31st December, 2012.

[10] Mike Haydell, "Unaccounted-For Gas", Reliant Energy-Entex P.O Box 550, New Iberia , LA 70562-0550

[11] UFG, Accounts and Annual Reports.

Assessment for the Model Predicting of the Cognitive and Language Ability in the Mild Dementia by the Method of Data-Mining Technique

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***Abstract*—Assessments of cognitive and verbal functions are widely used as screening tests to detect early dementia. This study developed an early dementia prediction model for Korean elderly based on random forest algorithm and compared its results and precision with those of logistic regression model and decision tree model. Subjects of the study were 418 elderly (135 males and 283 females) over the age of 60 in local communities. Outcome was defined as having dementia and explanatory variables included digit span forward, digit span backward, confrontational naming, Rey Complex Figure Test (RCFT) copy score, RCFT immediate recall, RCFT delayed recall, RCFT recognition true positive, RCFT recognition false positive, Seoul Verbal Learning Test (SVLT) immediate recall, SVLT delayed recall, SVLT recognition true positive, SVLT recognition false positive, Korean Color Word Stroop Test (K-CWST) color reading correct, and K-CWST color reading error. The Random Forests algorithm was used to develop prediction model and the result was compared with logistic regression model and decision tree based on chi-square automatic interaction detector (CHAID). As the result of the study, the tests with high level of predictive power in the detection of early dementia were verbal memory, visuospatial memory, naming, visuospatial functions, and executive functions. In addition, the random forests model was more accurate than logistic regression and CHIAD. In order to effectively detect early dementia, development of screening test programs is required which are composed of tests with high predictive power.**

***Keywords*—random forests; data mining; mild dementia; risk factors; neuropsychological test**

I. INTRODUCTION

Dementia is rapidly increasing in line with worldwide aging. As of 2013, the global dementia population was over 44 million, and it is expected to increase by more than three times to 135 million by 2050 [1]. In particular, the dementia population in Korea is increasing the fastest in the world. That is, it was 610,000 as of 2014, and it is predicted to increase two-fold every 20 years, multiplying by more than four times and reaching 2.71 million by 2050 [2].

The increase of the dementia population is expected to lead to enormous social and economic costs by increasing medical costs and various supporting costs. According to a 2014 survey by the National Health Insurance Service, one of two (48.7%) recipients of long-term senior care insurance was a senior with dementia, and the annual medical cost for dementia per patient was reported to be US$ 2,650, which is more than that for cardiovascular diseases (US$ 1,130) and diabetes (US$ 505) [3]. In addition, the number of seniors who received treatment as outpatients increased from 8.2 persons per 100,000 in 1999 to 66.4 in 2010, which is around an eight-fold increase. Total supporting costs for dementia in Korea as of 2010 were estimated to be US$ 7.4 billion, and they are predicted to increase two-fold every 10 years and reach US$ 37.3 by 2050, exceeding 1.5% of GDP [4]. Measures must be taken, as the increase in the number of seniors with dementia leads to considerable losses, not only for the patients but also for supporting families, local communities and the country as a whole.

Dementia is known to be a disease associated with the gradual decline of cognitive functions for which full recovery is impossible. Reports suggest that cognitive decline in dementia can be postponed if cognitive functions are systematically managed with medicines, such as cholinesterase inhibitors, in the early stages of dementia [5]. Thus, the focus is now on the treatment and early detection of dementia. In particular, prolonging the onset of dementia, even for just two years, with early detection and treatment can lower its prevalence rate by 20% and decrease dementia patients' problem behaviours [6]. Thus, the early detection of dementia is crucial from a clinical perspective.

The early detection of dementia is performed based on interviews, standardised neuropsychological tests and neurological tests. Among them, neuropsychological tests composed of assessments of cognitive/verbal functions have been widely used as screening tests to detect early dementia [7]. In particular, as the usefulness of verbal ability for detecting dementia has been verified [8], verbal tests have been emphasised as effective screening tests for dementia. Nevertheless, few Korean studies have investigated the characteristics of the cognitive and verbal functions of the elderly using standardised neuropsychological test tools.

Meanwhile, as pattern analysis becomes possible on big data, data-mining analysis, which detects the possible onset of a disease by drawing out reliable conclusions based on data, is gaining attention in the healthcare area. In particular, random forest, which is a machine-learning algorithm using the bagging approach, has high accuracy and predictive power, because it predicts the final target variables after creating and combining multiple decision trees with random sampling [9, 10].

This study developed an early dementia prediction model for Korean seniors based on the random forest algorithm and compared its results and precision with those of a logistic regression model and decision tree model based on chi-square automatic interaction detection (CHAID).

This study is organised as follows: Section II describes the study participants and analysed variables, and Section III defines random forest and explains the model development procedure. Section IV compares the results of the developed prediction model with those of existing models. Lastly, Section V presents conclusions and suggestions for future studies.

II. Methods

A. Study participants

Data were collected from face-to-face interviews with voluntary participants aged 60–90 living in Seoul and Incheon. Subjects with depression and those taking medicines that hamper cognitive functions were excluded.

The seniors with cognitive impairment were selected as a group suspected of dementia by using the Korean-Mini Mental State Examination (K-MMSE) [11], and dementia was screened with the diagnostic standards for Alzheimer's dementia of the Diagnostic and Statistical Manual of Mental Disorders-Fourth Edition [12] and standards for probable Alzheimer's disease of NINCDS-ADRDA [13]. In this study, patients with mild dementia were defined as those scoring 0.5–1 point on the Clinical Dementia Rating Scale [14]. A total of 418 seniors (135 males, 283 females) were finally analysed.

B. Measurements

Cognitive and verbal ability was measured by Seoul Neuropsychological Screening Battery(SNSB)[15], which is composed of cognitive tests such as attention (digit span forward, digit span backward), verbal memory (Seoul Verbal Learning Test (SVLT) immediate recall, SVLT delayed recall, SVLT recognition true positive, SVLT recognition false positive), visuospatial memory (Rey Complex Figure Test (RCFT) copy score, RCFT immediate recall, RCFT delayed recall, RCFT recognition true positive, RCFT recognition false positive), language ability (confrontational naming), visuospatial functions (Rey Complex Figure Test(RCFT) copy score), and executive function (Korean Color Word Stroop Test (K-CWST) color reading correct, K-CWST color reading error).

Independent variables were including digit span forward, digit span backward, confrontational naming, RCFT copy score, RCFT Immediate recall, RCFT delayed recall, RCFT recognition true positive, RCFT recognition false positive, SVLT immediate recall, SVLT delayed recall, SVLT recognition true positive, SVLT recognition false positive, K-CWST color reading correct, K-CWST color reading error.

III. Statistical Analysis

A. Development of mild dementia prediction model

In order to develop the mild dementia prediction model, this study divided data into training data (70%) and test data (30%). The random forest algorithm was used to develop the prediction model, and the results of the developed prediction model were compared with those of a decision tree based on the CHAID algorithm. The accuracies of the developed models were evaluated with the correct classification rate, and the importance of variables and major factors drawn out were compared respectively.

B. Random forest model

The random forest model is a data-mining technique that combines multiple decision trees in an ensemble classifier [16]. Random forest is composed of a training stage, which constructs multiple decision trees, and a test stage, which makes classifications or predictions when there are input vectors [17] (Figure 1).

As random forest is based on decision trees, it has a fast learning speed and the ability to process a large amount of data [18]. In addition, random forest has a higher prediction capability than a decision tree, and it can prevent overfitting [19].

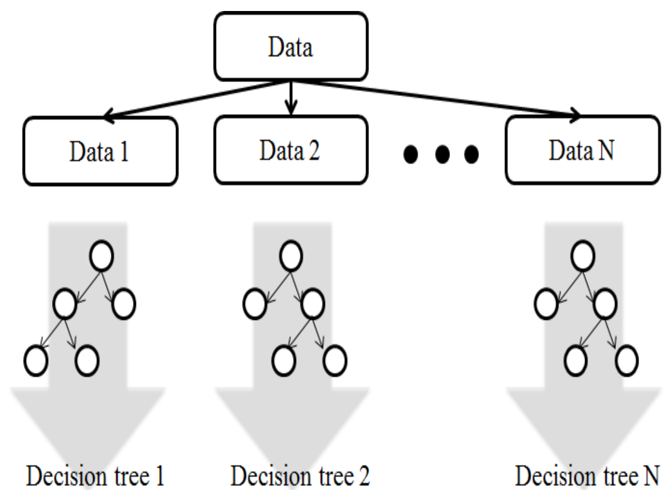

Fig. 1. Random Forests algorithm

IV. Results

A. General characteristics of participants

Among the 418 participants, 32.3% (n=135) were males and 67.7% (n=283) were females. The average age was 67.5 (standard deviation=4.3). Over 18.8% were high school graduates, and 76.5% were living with a spouse. Roughly 15.3% were current smokers, 26.5% were current drinkers and 33.8% exercised regularly (i.e. more than once a week). The prevalence rate of mild dementia was 8.4%.

B. Results of neuropsychological test for healthy seniors and seniors with mild dementia

The results of the neuropsychological test for healthy seniors and seniors with mild dementia are presented in Table 1. The results of the independent t-test revealed there were significant differences between healthy seniors and seniors with dementia for several factors. These included digit span forward, digit span backward, confrontational naming, RCFT copy score, RCFT immediate recall, RCFT delayed recall, RCFT recognition true positive, SVLT immediate recall, SVLT delayed recall, SVLT recognition true positive, SVLT recognition false positive, and K-CWST colour reading correct ($p<0.05$).

TABLE I. THE RESULTS OF NEUROPSYCHOLOGICAL TEST FOR HEALTHY ELDERLY AND ELDERLY WITH MILD DEMENTIA, MEAN±SD

Tests	Healthy elderly	Mild dementia
Attention		
Digit span forward*	5.34±1.78	4.35±1.13
Digit span backward*	3.83±1.25	2.65±1.11
Language function		
Confrontational naming*	40.83±12.18	31.52±8.84
Visuospatial function		
RCFT copy score*	26.73±9.01	21.88±10.81
Visuospatial memory		
RCFT immediate recall*	12.11±9.54	3.35±3.32
RCFT delayed recall*	10.88±8.35	2.45±2.86
RCFT recognition true positive*	9.12±2.53	7.38±3.15
RCFT recognition false positive	3.38±3.31	3.01±2.13
Verbal memory		
SVLT immediate recall*	17.35±6.31	10.08±3.56
SVLT delayed recall*	5.21±2.86	1.03±1.31
SVLT recognition true positive*	10.01±1.91	7.53±2.83
SVLT recognition false positive*	2.15±1.83	3.31±2.21
Executive functions		
K-CWST Color reading correct*	73.34±21.80	56.19±28.85
K-CWST Color reading error	4.89±6.31	9.36±10.38

*P<0.05

RCFT=Rey Complex Figure Test; SVLT=Seoul Verbal Learning Test; K-CWST=Korean Color Word Stroop Test

C. Accuracy comparison among random forest, logistic regression model, and decision tree

The prediction model was developed by using random forest, and its accuracy was compared with those developed using a logistic regression model and a decision tree (Table 2). The results of the analysis on the training data revealed that random forest showed very high accuracy of 72.5% (Figure 4, Figure 5). On the other hand, the accuracy of the decision tree was 71.2%, and the accuracy of the logistic regression model was the lowest with 68.7%.

In the test data, random forest showed the highest accuracy with 72.1%, while the logistic regression model had the lowest accuracy with 67.5%. Hence, random forest had the highest accuracy in both the training data and test data.

TABLE II. ACCURACY COMPARISON BETWEEN MODELS

Data	Model	Accuracy (%)
Training data	Logistic regression	67.9
	Decision tree	70.5
	Random Forests	73.7
Test data	Logistic regression	67.7
	Decision tree	70.8
	Random Forests	72.7

D. Comparison of neuropsychological tests for prediction of dementia

The results of the prediction models established based on a logistic regression model, a decision tree and random forest by using 14 neuropsychological tests to predict mild dementia are presented in Table 3.

In the logistic regression model, the prediction of mild dementia involved 12 tests, and its accuracy was 67.7%. These tests included digit span forward, digit span backward, confrontational naming, RCFT copy score, RCFT immediate recall, RCFT delayed recall, RCFT recognition true positive, SVLT immediate recall, SVLT delayed recall, SVLT recognition true positive, SVLT recognition false positive, and K-CWST colour reading correct.

The decision tree based on CHAID involved nine tests for the prediction of mild dementia, and its accuracy was 70.8%. These tests included digit span forward, digit span backward, confrontational naming, RCFT copy score, RCFT immediate recall, RCFT delayed recall, SVLT immediate recall, SVLT delayed recall, and K-CWST colour reading correct

Random forest involved 12 tests for the prediction of dementia, and its accuracy was 72.7%. These tests included digit span forward, digit span backward, confrontational naming, RCFT copy score, RCFT immediate recall, RCFT delayed recall, RCFT recognition true positive, SVLT immediate recall, SVLT delayed recall, SVLT recognition true positive, SVLT recognition false positive, and K-CWST colour reading correct.

TABLE III. COMPARISON OF NEUROPSYCHOLOGICAL TESTS FOR THE PREDICTION OF DEMENTIA

Model	Number of factors	Tests
Logistic regression	12	Digit span forward, digit span backward, confrontational naming, RCFT copy score, RCFT immediate recall, RCFT delayed recall, RCFT recognition true positive, SVLT immediate recall, SVLT delayed recall, SVLT recognition true positive, SVLT recognition false positive, K-CWST color reading correct

Decision tree	9	Digit span forward, digit span backward, confrontational naming, RCFT copy score, RCFT immediate recall, RCFT delayed recall, SVLT immediate recall, SVLT delayed recall, K-CWST color reading correct
Random Forests	12	Digit span forward, digit span backward, confrontational naming, RCFT copy score, RCFT immediate recall, RCFT delayed recall, RCFT recognition true positive, SVLT immediate recall, SVLT delayed recall, SVLT recognition true positive, SVLT recognition false positive, K-CWST color reading correct

V. Conclusion

The early diagnosis of dementia is important, because it not only reduces the number of cases that progress into dementia but also eases the individual and social burden of support for dementia patients.

As a result of the development of the early dementia prediction model for Korean seniors based on the random forest algorithm in this study, a number of factors were verified to be important indices in detecting mild dementia. These included digit span forward, digit span backward, confrontational naming, RCFT copy score, RCFT immediate recall, RCFT delayed recall, RCFT recognition true positive, SVLT immediate recall, SVLT delayed recall, SVLT recognition true positive, SVLT recognition false positive, and K-CWST colour reading correct.

Numerous studies have reported that verbal memory, visuospatial memory and naming are effective tests for distinguishing seniors with early dementia from healthy seniors [20, 21]. In particular, naming is known to be the most sensitive test for predicting the progress into dementia [8]. In addition, among the various neurological functions that decline with aging, delayed recall and selective attention have been reported to be the most sensitive items for predicting the onset of dementia from mild cognitive impairment [22].

Meanwhile, Artero et al. (2003) reported that the progress from mild cognitive impairment to dementia was best predicted when verbal memory and visuospatial ability were assessed together [23]. Moreover, in a cohort study on local communities, Dickerson et al. (2007) reported that the decline of not only verbal memory but also executive functions affects the progress into dementia [24]. These results imply that integrated assessment including verbal memory, visuospatial memory and performing ability is important in predicting cognitive decline and dementia in old age.

According to the results of the comparison of the accuracies of random forest, the logistic regression model and the decision tree, the accuracy of random forest was the highest. This is presumed to be because random forest is based on a bootstrap aggregating algorithm that creates various decision trees out of 500-odd bootstrap samples. While the decision tree has a risk of overfitting, random forest has higher accuracy than the decision tree, since it is based on a bootstrap aggregating algorithm that predicts target variables through means or probability [19, 25, 26]. Random forest is deemed to be more effective in conducting prediction analysis by using data with many variables to measure, since it draws out multiple training data, forms trees and predicts target variables.

The results of this study imply that verbal memory, visuospatial memory, naming, visuospatial functions and executive functions are cognitive domains that should be included before others in neuropsychological assessment to screen for mild dementia. In addition, in order to effectively detect early dementia, the development of screening test programmes composed of tests with high predictive power is required.

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References

[1] World Health Organization and Alzheimer's Disease International, Dementia: A Public Health Priority 2013. Geneva, World Health Organization, 2013.

[2] Ministry of Health and Welfare, 2012 survey of dementia prevalence. Seoul, Ministry of Health and Welfare, 2013.

[3] National health insurance service, Organization of dementia care in 2014 basic education. Seoul, National Health Insurance Service, 2014.

[4] S. W. Kim, Status of dementia management. Seoul, National Assembly Budget Office, 2014.

[5] P. Anand, and B. Singh, A review on cholinesterase inhibitors for Alzheimer's disease. Archives of Pharmacal Research, vol. 36, no. 4, pp. 375–399, 2013.

[6] National Health Insurance Institute, Analysis of medical use of Alzheimer's disease 2013. Sejong, Ministry of Health and Welfare, 2013.

[7] S. Weintraub, D. Salmon, N. Mercaldo, S. Ferris, N. R. Graff-Radford, H. Chui, E. Peskind, W. Dietrich, D. L. Beekly, W. A. Kukull, and J. C. Morris, The Alzheimer's disease centers' uniform data set: The neuropsychological test battery. Alzheimer Disease & Associated Disorders, vol. 23, no. 2, pp. 91–101, 2009.

[8] F. Boller, J. T. Becker, A. L. Holland, M. M. Forbes, P. C. Hood, and K. L. McGonigle-Gibson, Predictors of decline in Alzheimer's disease. Cortex, vol. 27, no. 1, pp. 9–17, 1991.

[9] G. Biau, Analysis of a random forests model. The Journal of Machine Learning Research, vol. 13, no. 1, pp. 1063–1095, 2012.

[10] A. Shameem, and D. Manimeglai, Analysis of significant factors for dengue infection prognosis using the Random Forest Classifier. International Journal of Advanced Computer Science and Applications, vol. 6, no. 2, pp. 240–245, 2015.

[11] C. Han, S. A. Jo, I. Jo, E. Kim, M. H. Park, and Y. Kang, An adaptation of the Korean mini-mental state examination in elderly Koreans: demographic influence and population-based norms. Archives of gerontology and geriatrics, vol. 47, no. 3, pp. 302–310, 2008.

[12] American Psychiatric Association, Diagnostic and statistical manual of mental disorders American Psychiatric Association. Washington DC, American Psychiatric Association, 1994.

[13] B. Dubois, A. Slachevsky, I. Litvan, and B. Pillon, The FAB: a Frontal Assessment Battery atbedside. Neurology, vol. 55, no. 11, pp. 1621–1626, 2000.

[14] J. C. Morris, Clinical dementia rating: a reliable and valid diagnostic and staging measure for dementia of the Alzheimer type. International psychogeriatrics, vol. 9, no. 1, pp. 173–176, 1997.

[15] Y. Kang, and D. L. Na, Seoul neuropsychological screening battery. Incheon, Human brain research & consulting co, 2003.

[16] L. Breiman, Random forests. Machine learning, vol. 45, no. 1, pp. 5–32, 2001.

[17] S. N. Devi, and S. P. Rajagopalan, A study on feature selection techniques in bio-informatics. International Journal of Advanced Computer Science and Applications, vol. 2, no. 1, pp. 138–144, 2011.

[18] S. Hussain, and G. C. Hazarika, Educational data mining model using rattle. International Journal of Advanced Computer Science and Applications, vol. 5, no. 6, pp. 22–27, 2014.

[19] H. Byeon, A prediction model for mild cognitive impairment using random forests. International Journal of Advanced Computer Science and Applications, vol. 6, no. 12, pp. 8–12, 2015.

[20] M. C. Greenaway, L. H. Lacritz, D. Binegar, M. F. Weiner, A. Lipton, and C. M. Cullum, Patterns of verbal memory performance in mild cognitive impairment, Alzheimer disease, and normal aging. Cognitive and Behavioral Neurology, vol. 19, no. 2, pp. 79–84, 2006.

[21] M. D. Calero, M. L. Arnedo, E. Navarro, M. Ruiz-Pedrosa, and C. Carnero, Usefulness of a 15-item version of the Boston Naming Test in neuropsychological assessment of low-educational elders with dementia. The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, vol. 57, no. 2, pp. 187–191, 2002.

[22] E. Mariani, R. Monastero, and P. Mecocci, Mild cognitive impairment: a systematic review. Journal of Alzheimer's Disease, vol. 12, no. 1, pp. 23-35, 2007.

[23] S. Artero, M.C. Tierney, J. Touchon, and K. Ritchie, Prediction of transition from cognitiveimpairment to senile dementia: a prospective, longitudinal study. Acta Psychiatrica Scandinavica, vol. 107, no. 5, pp. 390–393, 2003.

[24] B. C. Dickerson, R.A. Sperling, B.T. Hyman, M.S. Albert, and D. Blacker, Clinical prediction of Alzheimer disease dementia across the spectrum of mild cognitive impairment. Archives of General Psychiatry, vol. 64, no. 12, pp. 1443-1450, 2007.

[25] D. T. Larose, Discovering knowledge in data: an introduction to data mining. Hoboken, John Wiley & Sons, 2014.

[26] K. L. Lunetta, L. B. Hayward, J. Segal, and P. Van Eerdewegh, Screening large-scale association study data: exploiting interactions using random forests. BioMed Central genetics, vol. 5, no. 1, oi: 10.1186/1471-2156-5-32, 2004.

Impact of IT Resources on IT Capabilities in Sudanese Insurance and Banking Sectors

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***Abstract*—The previous studies that applied the Resource Based View (RBV), to examine the impact of IT resource on IT (Information Technology) competencies, often show different results. This study intends to investigate the impact of IT resources (core communication technology, group collaboration enterprise competences "inter-organization system usage") on IT capabilities (infrastructure, empowerment and functional capabilities) trying to discuss some empirical limitation of testing RBV such as able to disentangle the effects from a variety of sources, and how IT resources complement with other IT resources. Data were collected from 83 IT employees involved in Sudanese banking and insurance sector. A questionnaire was used to collect data. Reliability and factor analysis was conducted to ensure goodness of the data; regression analysis conducted to test the relationships between variables. The findings of this study do disentangle the effects on IT capabilities from a variety of sources. Moreover, it shows how IT resource complements each other in order to generate the outcome of capability.**

Keywords*—*IT resource, IT capabilities; RBV; process level; banking sector; insurance sector; Sudan

I. INTRODUCTION

Decades of globalization have witnessed worldwide competition, which leads to a rapid consolidation of systems-Integrator firms and their supply chains [1]. Accordingly, IT is being an important resource that can facilitate growth and development in both the developed and developing economies [2]. Thus, many firms try to sustain their competitive advantage, which can be built through developing competitive strategies that based on IT.

However, the relationship between resources and capabilities (including both IT resources and capabilities) are considered key elements in electing a business strategy which necessary for achieving a sustainable competitive advantage [3]. Moreover, the mechanisms through which the resources and capabilities are configured and deployed can be a source of competitive advantage [4]. Many attempts have been made to understand resource and capabilities using RBV but, so many things remain unclear such as the microstructures of organizational capabilities and how they are established and developed. Moreover, the techniques of identifying, assessing, and developing resource and capability are underdeveloped [3].

Thus, there is a need of typologies that would classify resources/capabilities in order to recognize their contribution to the performance or sustainability of competitive advantage. Besides, make an explanation of how RBV sustains competitive advantage or performance through a clear difference between the capacity building mechanisms (capabilities at different levels), acquiring and possessing mechanism (which includes both resources and capabilities) versus the processes of deploying that capacity [5]. Other limitations of RBV are concerning the mechanism through IT resource and capability is the RBV does not give clarification of how IT resource complements each other in order to generate capability [6].

RBV also suffers from some empirical limitations when used to distinguish the impact of IT resource on IT capabilities such as RBV fail to discriminate the impacts of various resource/capabilities in order to isolate the source of advantage [7, 8]. Thus, the results will not be verified [9].

Many studies were conducted to evaluate the effects of information systems on the organization's performance in the Sudanese context. These studies do not pay enough attention to the mechanism through which IT resources affect IT capabilities [10, 11]. Accordingly, there is little known about the mechanism through which IT resources affect IT capabilities in Sudan as one of the developing countries. This paper attempts to fill the gap in the knowledge about the relationship between IT resources and capabilities based on RBV. The focus is in the relationships among IT usage of information systems, and some inter-organizations, system usage (such as enterprise computing technology and group collaboration technology) and the value creating from those resources in terms of their capability performance at the process level. The objective is to enable the managers to decide which specific constructs of the core IT resources should be taken into consideration in order to improve their current inter-organizational systems or to build a better future inter organization system that can improve the performance of the firm at the process level. Moreover, improve some implication of RBV.

Accordingly, this paper is organized as follows, the first section discusses some problems of RBV concerning capabilities and resources, and various classifications of resources and capabilities and their advantages and disadvantages aiming to select the suitable classifications to test the mechanism through which IT resource influence IT capabilities. The second section detailed the proposed research model based on RBV, which link the IT resources and IT capabilities, which narrowly define of of IT resource and capabilities, thus enable to distinguish the impacts of each IT resources on IT capabilities. accordingly, make it easier for the decision maker to evaluate the effects of IT in the course of business functionality, and easier for a designer to grip the actual need of the organization. Moreover, enable to overcome the empirical limitation of testing RBV " to disentangle the effects from a variety of sources, and how IT resources complement with other IT resources" The fourth section explain research methodology, while the fifth section presents the data analysis and the results obtained. The last section discussed the findings of the research, including theoretical and managerial implications and actions of research.

II. IT Resource And Capabilities

A. RBV and IT resources and capabilities:

The central premise of RBV addresses the fundamental question of why firms differ in their performance and how they can achieve and sustain competitive advantage [12]. RBV theory has been applied to analyze the impact of information technology on business performance. This theory considered IT as of organizational resource that can enhance organizational capabilities and eventually lead to higher performance. This happens when IT capabilities/resource complement other constructs (including other resources or capabilities) that is a change in the level of one resource is offset by a change in the level of another resource [13].

However, there are some criticisms for RBV concerning resource and capability, for example the typologies of resources and capabilities are classified differently by different writers'[14]. Moreover, some researchers do not distinguish between the concept of capability and the concept of resource [12]. Furthermore, the outcome of complement IT resources with organizational resources, is not shown in the present conceptualization of the RBV [6].

Many challenges in empirically testing the RBV constructs are also observed, for example, the RBV is unlikely to be able to disentangle the effects from a variety of sources such as industry, environment, and strategy [8]. Thus, they recommend using a detailed, field-based comparison of the selected firms to uncover sources of advantage. Ray, Barney, and Muhanna [15] highlight the problem that occurs when the validity of the RBV is tested by researching the effect of certain firm resources on overall firm performance. As firm performance is a highly aggregated variable, they suggest that research should instead be carried out on the effect of certain resources on business processes. However, Foss [16] views that the RBV needs not to restrict its domain of application to the firm and he recommends to add some more fine-grained analysis by directing attention to the resources that underlie barriers to mobility and entry. Thus, could help to understand how resources contribute to performance and how resources influence competitive dynamics.

Many researchers are investigating how IT resources relate to IT capabilities and performance. Some papers focus on the direct relationship between resources and performance; many recent papers also investigate the mediating of organizational capabilities between resources and performance [17]. Other researchers examine the need for effective deployment of appropriate IT assets to create business value, through the intermediate stage such as better business competencies and processes, this in turn, affect firm performance [18]. Accordingly, the contribution of IT to firm performance, which is investigated by using RBV gives inconclusive findings. To highlight this problem a Meta analysis is conducted to investigate the results of previous research that based on RBV. The results suggest that mediation of organizational capabilities can better explain the relationship between organizational resources and firm performance than the direct relationship without organizational capabilities [17]. To sum up, the RBV has helped to improve the understanding of the usefulness of information technology and the importance of IT resources. However, the mechanism path leading IT resources to yield organizational benefits remains a "black box," [19]. Some of the problems of this black box are concerned with IT resource and capabilities, therefore, the following section highlights the classifications of IT resources and capabilities and problems concerning them.

B. IT resources:

IT resources can be defined in term of assets (tangible or intangible) for examples information systems hardware, software and network infrastructure [20]. The organization consists of different level accordingly there is a need for different specialties, and different kinds of system usage (resource) on the organization; thereby there is impossible to satisfy those information needs through one system [21]. For example IT resources are classified into the following: The classification which is related specifically to organization level [21, 22]; the classification which focus on organizational activities [21, 23]; the classification of systems that are used in the whole organization [24]; the classifications according to the nature of interdependencies that exist in the different project's [25]; and The classification that related to some IT capabilities [26].

Understanding information system usage classification (resources) helps in visualizing the potential applicability of different approaches for applying IT and recognized strengths and weaknesses of approaches. IT resources classifications are overlapped, such as denoting some IT applications used in a specific functional area classification, and then used in management level classification. Thus, sometimes difficult to understand what someone else means by using the categories related terms [27]. Despite of that, this overlapping indicates that information systems provide information for a variety of managerial levels and business functions [23].

C. IT capabilities:

IT capabilities are referred to as a skill, for examples, technical, managerial skill and the ability that transform inputs to outputs [20]. There are different classifications of IT capabilities, the most important classifications are according to: the use in the value chain [3, 28]; the IT operational focus (internally or externally) [29, 30, 31]; their contributions to competitive advantage [32]; depending on the tangibility of organizational resources [33], and IT resources classifications [23].

IT capability classifications have some limitations such as the terminology used by authors which is widely varied. Moreover, the classifications are sometimes overlapping due to the objectives and perspectives of the authors. The overlaps in the classification of capabilities lead to none correspond of operational definition and conceptual definition, because it does not capture the essence of the multidimensional nature of the capability [34].

III. Model Specification and Hypotheses

The model is based on RBV as it can provide a valuable way to evaluate the strategic value of information systems resources. It also provides guidance to differentiate among various types of information system usage, including the important distinction between resources and capability. Furthermore, the theory can facilitate cross-functional research [13].

The model shown in figure 1 is unlike other previous framework that explores relationship between IT resources and IT capabilities which is narrowly defined to fit into a particular context. Such definition has the advantage over abstract, which may inappropriately combine distinct resources under a single label, thereby weakening the true relationship validity [13].

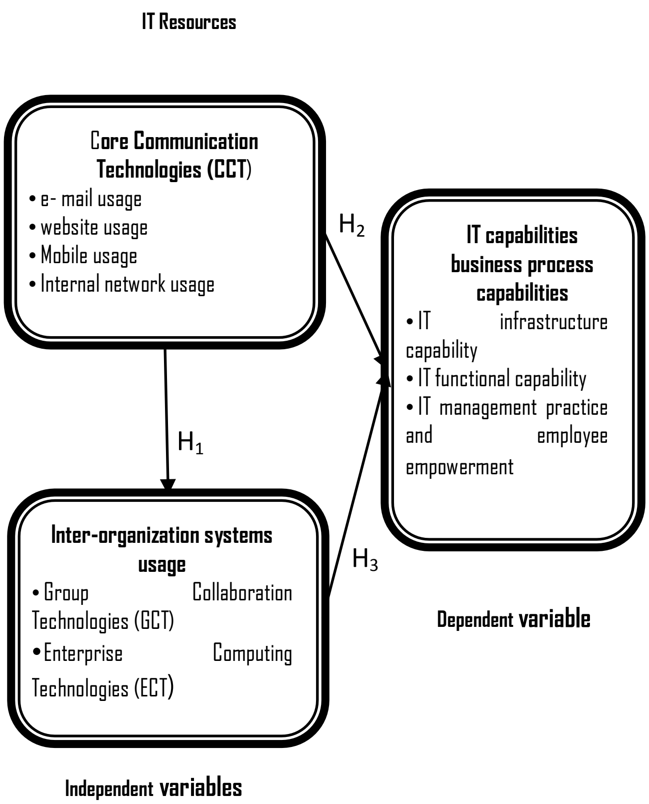

Fig. 1. The role of its resources on it capabilities framework

The main components of the framework are: IT resources which represent the independent factors; the capabilities of IT which represent the dependent variables. IT resources to construct is chosen through adapting Bardhan et al. [25] classification which depends on the nature of interdependencies that exist in different projects. IT according to Bardhan et al. [25] is classified into core communications technology, group collaboration technology and enterprise computing technology. These classifications make it easier for the designer to decide what resource is needed in order to generate some capability.

Enterprise computing technology and grouped collaboration technology are termed as inter-organizational systems and put as separate IT construct. The objective is to enable the managers to decide which specific constructs of the core IT resources should be taken into consideration in order to improve their current inter-organizational systems or to build a better future inter- organizational systems that can improve the performance of the firm at the process level. Moreover, the separation of constructing into inter organizational systems and core communication technology can describe details fine grain classifications of IT resources and capabilities to disentangle the effects on performance from a variety of sources. Moreover, it shows how IT resources complement each other in order to generate the outcome of capability. Thus, the research model discuses some limitations of RBV.

IT capability classifications are chosen through adapting Tallon and Kraemer [35] classification of IT business value capabilities at the process level and IT infrastructure flexibility and Iansiti and Sarnoff [28] classification across the value chain. These classifications are chosen because they are closely aligned with traditional business operations processes and IT systems, accordingly the decision maker find it easier to manage the intrinsic complexity of their businesses [28]. The combinations of the classifications of resources and capabilities that had chosen to make it easier for the designer to grip the actual need of the organization, as the decision maker can easily evaluate the effects of IT in the course of business functionality.

A. IT core resources and inter-organization system resource:

The Enterprise resource planning ERP software vendor generally certifies which hardware (and hardware configurations) must be used to run the ERP system. Accordingly, the availability of IT core resources in the organization can influence the usage of enterprise computing technology[36, 37]. Therefore, hypothesis, one can be stated as:

H_1: core communication technologies usage has a positive impact on inter-organizational systems.

B. IT core resources and IT capabilities

Previous literature indicates organizational resources are the source of a firm’s capabilities. Capabilities are often developed in specific functional areas or in a part of a functional area. Some scholars indicate to the direct relation between IT resources and IT capabilities such as Ravichandran and Lertwongsatie [38]. Hypothesis two can be stated as:

H_2: core IT usage has a positive relation with IT capabilities.

C. Inter-organization system usage and IT capabilities:

ERP applications can create the capabilities of cooperation and communications with external partners accordingly it supports strategic flexibility [39 , 40 , 41 , 42]. Moreover, McCredie and Updegrove [43] indicate that new application of enterprise computing technology requires a great deal of regulations to meet performance expectations for user such as IT infrastructure can provide the level of performance users expect from a modern enterprise application. Moreover, customer relationship system usage can generate marketing capability to the organization [44, 45]. Hypothesis three can be stated as:

H_3: inter-organization system usage can effects on IT business process capability.

IV. METHODOLOGY

A. Measurement

This study is cross-section, descriptive, quantitative-correlation-explanatory study. All Variables are measured through questionnaires. Some questionnaire items were adapted from existing studies. The items are then modified to reflect the applicability within Sudanese context. Table 1 provides a summary of the variables utilized and supporting literature. All the items in the questionnaire are rated on a five-point Likert scale. The IT capabilities items are designed in a manner which has the ability to measure the impacts of IT on efficiency; effectiveness and competitiveness thereby enable to measure the impact of IT resources on IT capability performance at the process level.

TABLE I. SUMMARY OF THE VARIABLES UTILIZED AND SUPPORTING LITERATURE

Dimension	Description	Support reference
IT resources		
Core communication	Includes: e- mail usage, internal network usage, website usage and mobile communication technology.	Eraqi [46]; Bruque. et al [47]; Andam [48]; Merisavo [49]; Boadi and Shank [50]; Arunthari [51]
Enterprise computing technology	Institutionalize sequential interactions between work units and support structured sequential interactions between the users which enable them to access and exchange data in a structured format.	Bardhan, et al. [25]
Group collaboration technologies	Collaboration among individuals engaged in a common task using electronic technology.	Bardhan, et al. [25]
IT capabilities		
IT infrastructure capability	Includes: Connectivity and modularity of software, Compatibility integration capabilities) and adaptability (IT human skill).	Tallon and Kraemer [35]; Tallon [52]
IT management practice and employee empowerment	Includes: IT strategic capability, IT planning, IT coordination capability.	Zhang [40]; Tallon [52]; Kearns and Lederer [53]
IT functional capabilities	Includes: IT production capability, customer relationship and service enhancement capabilities, marketing management capabilities, supplier's partnership/collaboration, IT financial capabilities.	Zhang [40]; Kearns and Lederer [53]; Tallon and Kraemer [35]; Tallon [52]

B. Sampling

The population of this study is banking and insurance institutions that have worked for more than five years, because these institutions have the ability to evaluate their IT resources and capabilities more than the others. Moreover, it is one of the largest and oldest sectors and a successful company may pay attention to the benefits of information systems [54]. The whole population has chosen as a sample for this research. The unit of analysis is IT senior staff member who can evaluate the effects of IT on performance. A single respondent is used in each business unit, because only one or two members of the top management team had a complete picture in each department. A total number of 83 questionnaires are distributed to 84% of the total targeted institutions. The sample has the following characteristics: (1)77.7 % of the banking sector; (b) the average age of the respondents is 36.5 years; (c) 83.4% male more than 92% are graduated or postgraduate.

V. RESULTS

A. Factor analysis

The factor analysis in this paper is conducted in order to identify the underlying dimensions of IT resources and capabilities and also to determine if the dimensions could be summarized into smaller sets of factors, thereby allowing the formation and refinement of the theory. Besides, providing construct validity evidence of self-reporting scales.

Although the three types of IT resources constructs (core communication technology, group collaboration, and enterprise computing technology) are treated as one construct in some previous study such as Bardhan, et al. [25], in this study it is treated as a separate construct in order to add some more fine-grained analysis to the understanding firm level IT resources. In addition, it helps to test constructing convergence with maximally similar sets of variable as well as to avoid violating recommended minimal sample size to parameter estimate ratios suggested by Kerlinger and Lee [55].

Table 2 shows the results of factor analysis which is performed on 10 items of core communication technology statements. Four-factor solution was obtained which satisfactorily met the requirements (the items have factor loading greater than 0.65). Therefore only three factors will explain IT resources which can be explained as follows: The first factor includes only items of e-mail usage and website usage. The second factor consists of the items of mobile usage. The third factors consist of two factors from internal network usage. Accordingly, core communication technology is divided into three components the first one is labelled as internet usage, which includes both website usage and e-mail usage. The second components are the mobile usage, and the third one is an internal network usage. Cronbach's Alpha for the first component is 0.847, and for component to 0.611 and component three 0.593.

TABLE II. FACTOR ANALYSIS OF CORE COMMUNICATION TECHNOLOGY

Items	Factor loading		
	1	*2*	*3*
The use of e-mail for facilitating the delivery of services is high.	0.76		
The use of e-mail for receiving client complaints and inquiries is high.	0.773		
The use of e-mail for facilitating the business office such as call for meetings, inquiries, file transfer, etc. is high.	0.809		
Web site usage			
The use of website for facilitating the selling and buying process is high.	0.794		
Mobile usage			
The use of mobile for facilitating receiving client complaints and inquiries is high.		0.651	
The use of mobiles for facilitating sending periodic reports to clients such as balance sheet reports are high.		0.734	
The uses of mobiles for facilitating the business office works such as call for meetings, inquiries, etc. is high.		0.758	
Internal network			
The use of internal network interconnects the computers and the building of the institution is high.			0.853
The use of internal network interconnects the computers and the institution branches are high.			0.826
Eigenvalues	3.490	1.485	1.386
Percentage of Variance Explain	31.726	13.502	12.601

The result of factor analysis for group collaboration technology enterprise computing technology is shown in the table 3 suggested that all assumptions for factor analysis have been met. Cronbach's Alpha for group collaboration technology is 0.633 and for enterprise computing technology is 0.788.

TABLE III. FACTOR ANALYSIS OF GROUP COLLABORATION TECHNOLOGY AND ENTERPRISE COMPUTING TECHNOLOGY

Items	Factor loading
Group collaboration	
The use of Instant Messaging Software is high.	0.857
The use of Video-Conferencing Technologies is high.	0.857
Eigenvalues	1.468
Percentage of Variance Explain	73.393
Enterprise computing technology	
The use of Enterprise Application Software is high.	0.761
The use of Knowledge Management is high.	0.857
The use of Customer Relationship Management Software is high.	0.826
The use of Document management applications is high.	0.679
Eigenvalues	2.456
Percentage of Variance Explain	61.407

Factor analysis was done for three types of IT capability separately to test for constructing convergence with maximally similar sets of variable as well as to avoid violating recommended minimal sample size to parameter estimate ratios suggested by Kerlinger and Lee [55]. Table 4 shows the results of factor analysis of seven items of IT infrastructure capability. The results reveal that only five items explain IT infrastructure capability. Cronbach's Alpha for IT infrastructure capability is 0.770.

TABLE IV. FACTOR ANALYSIS OF IT INFRASTRUCTURE CAPABILITY

Items	Factor loading
Our systems are sufficiently flexible to link with external parties.	0.816
Institution databases are accessed through many different protocols.	0.683
Legacy systems within our institution do not hamper the development of new IT applications	0.734
Software applications can be easily transported and used across multiple platforms.	0.673
Our IT personnel have the ability to understand the priorities and objectives of the organization	0.653
Eigenvalues	3.028
Percentage of Variance Explain	43.6

The factor analysis of eight items from IT management practice and employee empowerment is conducted as shown in table 5, the result of analysis suggested that only two factors will explain IT resources which can be explained as follows: The first factor includes two items of strategic planning capabilities and one item from strategic capabilities and website usage, all of which indicate improvement in performance, accordingly, it termed as improvement capabilities. The second factor consists of two items of strategic capability which it termed as IT strategic capability. Cronbach's Alpha for the first component is $\alpha = 0.657$ and for the second component is 0.740.

TABLE V. FACTOR ANALYSIS OF IT MANAGEMENT PRACTICE AND EMPLOYEE EMPOWERMENT

Items	Factor loading	
	1	*2*
IT improves managerial decision-making.	0.692	
IT provides the institutional advantages such as lower costs or product differentiation.	0.791	
IT enhances the effectiveness of our overall performance.	0.660	
IT creates barriers to keep competitors from entering our market.		0.860
IT influences the buyer’s decision to switch to service.		0.844
Eigenvalues	3.390	1.342
Percentage of Variance Explain	37.664	52.576

Table 6 shows the results of factor analysis for IT functional capabilities. The results suggest that three-factor solution and only two factors will explain IT functional capability. Factor three which contain one item is deleted as recommended by Hinkin [56]. The first factor includes some items of IT production capability, financial capability. Thus, the first component is labelled as IT internal functionality. The second factor consists of some items of IT customer relationship and service enhancement capabilities, IT marketing capability. Thereby, this factor is termed as IT external functionality. Cronbach's Alpha for the first component is 0.887 and for the second component 0.850.

TABLE VI. FACTOR ANALYSIS OF IT FUNCTIONAL CAPABILITIES

Items	Factor loading		
	1	*2*	*3*
IT helps your institution to prepare different special financial reports.	0.918		
IT reduces the required time to prepare financial reports.	0.835		
IT helps reduce the costs of preparing financial reports.	0.799		
IT improves the quality of service.	0.712		
IT increases the number of clients who can be served per employee.	0.670		
IT enables sales people to increase sales per client.		0.904	
IT improves accuracy of sales forecasts.		0.889	
IT helps track market response to advertising campaigns.		0.723	
IT improves the institution's capability to reach clients at different geographic locations.		0.665	
IT helps track market response to pricing strategies.		0.662	
IT helps the institution get better services from their suppliers \partnership.		0.662	
IT enhances the capabilities of the institution to respond to the needs of different clients differently.		0.652	
IT allows economies of scale for the service.			0.687
Eigenvalues	6.657	2.238	1.115
Percentage of Variance Explain	44.378	14.922	7.432

Note that Cronbach's Alpha score of all dimensions is above or approaching 0.60, consequently we're able to meet Nunnally's [57] guideline that modest reliability in the range of 0.50 to 0.60 will suffice for exploratory research.

B. B. Hypotheses Testing:

Regression analysis is conducted in order to test the hypotheses state above. Hypothesis, one indicates to the relationship among core communications technology and group collaboration technology and enterprise computing technology. The result of regression analysis is shown in the table below.

TABLE VII. THE RELATIONSHIP BETWEEN IT CORE COMMUNICATIONS AND INTER- ORGANIZATIONAL SYSTEMS

Independent variables	Dependent variables	
	Group collaboration technology	*Enterprise computing technology*
	Beta	*Beta*
Internet usage	0.512***	0.511***
Mobile usage	0.121	0.184*
Internal network usage	0.215**	0.122
f value	17.629***	17.501***
r^2	0.401	0.399
Adjusted r^2	0.378	0.376
f change	17.629***	17.501***

Note: significant: *p<0.10, **p<0.05, ***p<0.01

Table 7 shows the results of regression analysis of core communication technology and enterprise computing technology indicate that the model that was significant (f= 17.501, p<0.01). Moreover, there is a positive relationship between internet usage and enterprise computing (ß= 0.511, p<0.01), and positive relation between mobile usage and enterprise computing technology (ß= 0.184, p<0. 1). The results also reveal that, group collaboration technology has significant correlations with internet usage (ß=0.512, p<0.01). Moreover, the internal network usage shows significant correlation with group collaboration technology (ß=0.215, p<0.05).

Hypothesis two indicates the relationship between inter-organization resources and IT capabilities. Table 8 shows the results of the regression analysis of the relationship between inter-organizational resource and IT capabilities. The results of the analysis suggest that enterprise computing technology has significant correlations with IT infrastructure capability (ß=0.331, p<0.05). Moreover, group collaboration technology has only significant relationship with IT external functionality (ß= 0.360, p<0.01). In addition to that, enterprise computing technology has significant correlation with the IT external functionality (ß=0.314, p<0.01).

TABLE VIII. THE RELATIONSHIP AMONG INTER- ORGANIZATIONAL SYSTEMS USAGE, IT INFRASTRUCTURE AND IT FUNCTIONAL CAPABILITIES

Independent variables	Dependent variables				
	IT infrastructure capability	*IT functional capability*		*IT management practice and employee empowerment*	
	IT infrastructure capability	*IT external functionality*	*IT internal functionality*	*IT performance capability*	*IT strategic capability*
	Beta	*Beta*	*Beta*	*Beta*	*Beta*
Group collaboration technology	0.102	0.360***	0.052	-0.042	0.164
Enterprise computing technology	0.331**	0.314***	.291**	0.432**	0.185
f value	7.875***	24.255***	4.799**	7.865***	4.484*
r^2	0.164	0.377	0.107	0.164	0.101
Adjusted r^2	0.144	0.362	0.085	0.143	0.078
f change	7.875***	24.255***	4.799**	7.865***	4.484*

Note: significant: *p<0.10, **p<0.05, ***p<0.01

The result also in table 8 shows that group collaboration technology has no significant correlation with IT internal functionality, while enterprise computing technology has significant correlation with IT internal functionality (ß=0.291, p<0.05). Also, the result reveals that group collaboration technology has no significant correlation with IT performance capability, while enterprise computing technology shows significant relation with IT performance capability (ß=0.432, p<0.05).

Hypothesis three indicates the relationship between core communications and other IT capabilities. Table 9 shows the results of regression analysis of core communications technology and IT capabilities. The internet usage (ß=0.253, p<0.05) and internal net usage (ß=0.204, p<0.1) have significant correlation with IT internal functionality, while mobile usage has no relation with IT internal functionality. Also, internet usage (ß=0.353 p<0.01), mobile usage (ß=0.239, p<0.05), and internal network (ß=0.176, p<0.1) has a significant correlation with IT external functionality. The results also, reveal that mobile (ß=0.478, p<0.01) usage has a significant correlation with IT infrastructure capability, while internet usage and internal network usage have no significant correlation with IT infrastructure capability.

TABLE IX. THE RELATIONSHIP BETWEEN CORE COMMUNICATIONS AND OTHER IT CAPABILITIES

Independent variables	Dependent variables				
	IT functional capability		IT infrastructure capability	IT management practice and employee empowerment	
	IT internal functionality	IT external functionality	IT infrastructure	IT performance capability	IT strategic capability
	Beta	Beta	Beta	Beta	Beta
Internet usage	0.253**	0.353***	0.095	0.256*	0.167
Mobile usage	0.131	0.239**	0.478***	0.185*	0.178
Internal network usage	0.204*	0.176*	0.171	0.141	0.160
f value	5.218***	11.183***	12.367***	5.330**	3.56*
r^2	0.134	0.298	0.320	0.168	0.119
Adjusted r^2	0.165	0.271	0.294	0.137	0.086
f change	5.218***	11.183***	12.367***	5.330**	3.560*

Note: significant: *p<0.10, **p<0.05, ***p<0.01

The results also, reveals that internal network usage (ß=0.256, p<0.1) and mobile usage (ß=0.185, p<0.1) have significant correlation with IT performance capability, while internal network usage has no significant correlation with IT performance capability. Figure 10 shows that the three core communication technology has no significant correlation with IT strategic capability.

VI. DISCUSSION AND CONCLUSION

This paper used the RBV to examine the mechanisms through which IT resources affect IT capabilities, by using a detailed model ,which enable to disentangle the effect of IT resource on IT capabilities at the process level, which is one of empirical limitations of testing RBV. This can provide a valuable way to evaluate the strategic value of information systems resources. Thus, enabling both decision maker and IT designer to evaluate the effects of IT in the course of business functionality

The results of study indicate that some cores of communication technology do affect enter-organization systems, such as internet usage, which affects both group collaboration technology and enterprise computing technology. Moreover, mobile usage affects enterprise computing technology and internal network usage affects group collaboration technology. This converges with Al-Mashari, [36] who indicates that IT core resource availability in the organization can influence the usage of enterprise computing technology.

The results of the study also indicate that some core communication technology affects IT capabilities such as the internet affects IT internal and external functionality, IT infrastructure capability and IT performance capability. Moreover, mobile technology affects IT external functionality, IT infrastructure capability and IT performance capability. This may be due to the fact that using mobile in financial services required high network connectivity and modularity of software capability [58]. Besides internal network usage affects both IT external and internal functionality. This may be due to the fact that information plays a role in building superior market capability because it is needed in satisfying latent needs, which exist and are satisfied [59] and the internal network can facilitate this process.

The results also partially support hypotheses three because inter organizational system usage affects some IT capabilities. For example group collaboration technology affects IT external functionality. While enterprise computing technology affects all IT capabilities except IT strategic capability.

It is worth mentioning that IT resources do not affect IT strategic capability. The result does not confirm with Laudon and Laudon [60] who indicates that networking facilitates strategic capabilities of information systems. This may be due to the fact “Sudan in the stage of capacity-building phases that may create change” as described by the NCT report [61]. However, to build such capability in modern application of strategic information system it needs to be based on internet connectivity with supplier and customer [62].

A. Theoretical and managerial implication:

The research framework provides a comprehensive snapshot of IT studies on organizational performance at the process level.

The research model defines the relationship between IT resources and IT capabilities which is narrowly defined to fit into a particular context. Such definition has the advantage of avoiding the more actionable managerial implications of the general RBV based framework, such as the narrow definitions helps to fine-tune the understanding of “resource specificity” and its impact on performance in a given setting [63].

The study bridges the existing gaps between theory and practice by overcoming some limitations of previous studies: for example the use of a single major IT capability or IT usage to explain the mechanism through which IT resources affects IT capabilities. Moreover, try to avoid some limitation of testing RBV as the findings of this study do disentangle the effects on IT capabilities from a variety of sources. Moreover, shows how IT resource complements each other in order to generate the outcome of capability.

Furthermore, the use of regression analysis enables testing a combination of resources and capabilities. These tests according to Barney [64] ‘gaining and preserving superiority in competitive markets depends on the set of core resources and capabilities that a firm has developed, acquired, and deployed in the competition arena’.

The study also, offers a detailed framework for measuring the level of IT usage and IT capabilities that support business functions and infrastructure, as well as IT management. This can be useful for both the internal assessment and for the evaluation of IT service providers. In addition to that, the study also offers a tool for the Sudanese decision makers in insurances and banking to evaluate IT capabilities in order to enable them prioritize among their companies’ gaps in IT capability compared to competitors. Thus, they can create a strategic plan that generates a greater return on IT investment.

B. Limitation:

This research suffers from the following limitations: The findings are difficult to generalize to new contexts due to using resources with particular forms of capabilities that are overly narrow and potential implication might become lengthy for practical research use [63].

The second limitation of this study is that it takes a static cross-sectional picture of the capabilities and business value which makes it difficult to address the issue of how capabilities are created over a run of several years [65].

References

[1] Nolan, P. and Zhang, J."Global Competition after The Financial Crisis". New left review 64, pp. 97–108, 2010 .

[2] Prasad, Acklesh. "Understanding IT business value creation and evaluation in least developed economies", Electronic Journal of Information Systems in Developing Countries. Vol. 47, No.1, pp. 1-18, 2011.

[3] Grant, R. Contemporary Strategy Analysis. Fifth Edition, Wiley-Blackwell, 2005.

[4] Gannon, C., and Lynch, P., Holden T.M. Harrington, D. "Does Sustainable Competitive Advantage Exist? And, if So, How Can It Be achieved?", paper present in: 13th Irish Academy of Management Conference, Cork Institute of Technology, 1st-3rd September, 2010.

[5] Kraaijenbrink J., Spender J.C. and Aard J. G. "The Resource-Based View: A Review and Assessment of Its Critiques", Journal of Management, Vol. 36 ,No. 1, pp. 349-372, 2010.

[6] Nevo, S. and Wade, M. R. "The Formation and Value of IT-Enabled Resources: Antecedents and Consequences of Synergistic Relationship", MIS Quarterly, Vol.34, pp.163-183, 2010.

[7] Bowen, H. P. & Wiersema, M. F. "Matching method to paradigm in strategy research: Limitations of cross sectional analysis and some methodological alternatives", Strategic Management Journal, Vol. 20, pp. 625-636, 1999

[8] Rouse, J. M. and Daellenbach, S.U. "Rethinking Research Methods for the Resource-based Perspective: Isolating Sources of Sustained Competitive Advantage", Strategic Management Journal .Vol.20,No.5 ,p.p 487-494, 1999.

[9] Armstong, C. E. & Shimizu, K. "A review of approaches to empirical research on the resource-based view of the firm", Journal of Management, Vol. 33, No. 6, pp. 959-985, 2007

[10] Abd Elmal, Z., E. "Effect of Using Management Information System on Functional Performance: A Case Study of the Islamic Cooperative Development", Unpublished Doctoral dissertation, Sudan: University of Sudan of Science and Technology, 2009.

[11] Ahmed, O. "Role of E- Commerce in Establishing E-Government Infrastructure: An Applied Study of the Sudan", Unpublished Doctoral dissertation, Sudan: University of Sudan of science and Technology, 2010.

[12] Väyrynen, K. "Evolution of Software Business In Industrial Companies: Resources, Capabilities and Strategy", Academic dissertation to be presented with the assent of the Faculty of Science of the University of Oulu For Public Defence In Auditorium IT116, Linnanmaa, 2009.

[13] Wade, M., and Hulland, J. "The Resource-Based View and Information Systems Research: Review, Extension, and Suggestions for Future Research", MIS Quarterly, Vol. 28, No. 1, pp. 107-142, 2004.

[14] Tuan ,N. ,and Yoshi T. "Organizational Capabilities, Competitive Advantage and Performance in Supporting Industries in Vietnam", Asian Academy of Management Journal, Vol. 15, No. 1, pp.1–21, 2010.

[15] Ray G., Barney J.B. and Muhanna W.A. "Capabilities, Business Processes, and Competitive Advantage: Choosing the Dependent Variable in Empirical Tests of the Resource-Based View", Strategic Management Journal Vol. 25, No.1, pp 23–37, 2004.

[16] Foss, N. "The Resource-Based Perspective :An Assessment and Diagnosis of Problems", DRUID Working Papers 97-1, DRUID, Copenhagen Business School, Department of Industrial Economics and Strategy, Aalborg University, 1997.

[17] Liang, T. and You, J.J "Resource-based View in Information Systems Research: A Meta-Analysis", Pacific Asia Conference on Information Systems (PACIS) PACIS 2009 Proceedings Association for Information Systems, 2009.

[18] Soh, C., and Markus, l. M. "How to create Business Value: A Process Theory Synthesis", Proceedings of the 16th International Conference on Information Systems, 29 – 42, ACM Publications, New York, 1995.

[19] Melville, N., Kraemer, L.K., and Gurbaxani, V. "Information Technology and Organizational Performance: An Integrative Model of IT Business Value", MIS Quarterly, Vol. 28, No. 2, pp. 283-322, 2004.

[20] Oh,B. L, Leong ,X.Y. , and Teo, H.H. "A Model of IT-enabled Organizational Integration and Sustained Competitive Advantage", Paper present at 20th Bled eConference eMergence: Merging and Emerging Technologies, Processes, and Institutions June 4-6, 2007; Bled, Slovenia, 2007.

[21] Laudon , K. and Laudon, J. Management Information Systems: Managing the Digital Firm. Prentice Hall, 2006.

[22] O'Brien, A. J. Introduction to information systems. Tata McGraw-Hill Publishing Company limited New Delhi, 2005.

[23] McAfee, A. "Mastering the three worlds of information technology", Harvard Business Review, Vol.84, No.11, pp. 141-149, 2006.

[24] Boddy, D., Boonstra, A., and Kennedy, G. Managing Information Systems an Organization Perspective. Prentice Hall Finical Times, 2005.

[25] Bardhan, I.V., Krishnan, V., and Lin, S. "A Model to Measure the Business Value of Information Technology: the Case of Project and Information Work", University of Texas Working Paper, March 2005.

[26] Bharadwaj, S.A. "A resource-based perspective on information technology capability and firm performance: an empirical investigation", MIS Quarterly, Vol. 24, No. 1, pp. 169–196, 2000.

[27] Alter, s Information Systems: foundation of E -business. Prentice-Hall, Inc. A Pearson Education Company, 2004.

[28] Iansiti, M. and Sarnoff, D. Enterprise IT Capabilities and Business Performance, Keystone Strategy, 2006, incdownload.microsoft.com/.../Development.Whitepaper.KeystoneStrate

[29] Feeny, F.D., and Willcocks, P. L. "Core IS Capabilities For Exploiting Information Technology", Sloan Management Review, Vol.39, No.3, pp. 9-21, 1998.

[30] Lee, C., Lee, K., and Pennings, M. J. "Internal Capabilities, External Networks, and Performance: A Study on Technology based ventures", Strategic Management Journal Vol. 22, pp. 615–640, 2001.

[31] Hulland, J. Wade, M. R., and Antia, K. D. "The Impact of Capabilities and Prior Investments on Online Channel Commitment and Performance", Journal of Management Information Systems. Vol. 23. No. 4. pp. 109–142, 2007.

[32] Bi, R., Smyrnios, K.X., and Kam, B. "Information System Capabilities as a Driving Force in Enhancing Organizational Performance: An Empirical Study", 14th Pacific Asia Conference on Information Systems (PACIS). Taipei, Taiwan, 2010.

[33] Araya, S., Chaparo, J., Orero, A., and Joglar, H. "An integrative view of IS/IT and organizational resources and capabilities", Issues in Informing Science and Information Technology, Vol. 4, pp. 629-639, 2007.

[34] Addas, S., and Pinsonneault, A. IT capabilities and firm performance: A resource-based, alliance perspective. 2007. available at: http://ojs.acadiau.ca/index.php/ASAC/article/viewFile/1067/926

[35] Tallon, P. P., and Kraemer, L. K. "Using Flexibility to Enhance the Alignment between Information Systems and Business Strategy: Implications for ITS Business Value, Research on Information Technology and Organizations (CRITO), University of California, Irvine, 2003.

[36] Al-Mashari, M. "Enterprise resource planning (ERP) systems: a research agenda", Industrial Management and Data Systems. Vol. 102, No. 3, pp. 165-170, 2000.

[37] SMUTNY, Zdenek and BECAN Martin "The use of enterprise social networks in organizations from the perspective of generation y in the

czech republic", Scientific Annals of Economics and Business, 63 (1), 91-104, 2016

[38] Ravichandran, T. and Lertwongsatien, C. "Effect of Information Systems Resources and Capabilities on Firm Performance: A Resource-Based Perspective", Journal of Management Information Systems, Vol.4. N0.21,pp. 237-27, 2005.

[39] Adhikari, S. Sustained Competitive advantage through ERP Systems based knowledge and process innovation. A short literature review on topic, Hanken, Helsinki, 2007.

[40] Zhang, M. J. "Information Systems, Strategic Flexibility, and Firm Performance: An Empirical Investigation", Journal of Engineering and Technology Management, No. 22, Vol. 3, pp.163-184, 2005.

[41] Tian, J., Wang, K., Chen, Y. and Johansson, B. "From IT deployment capabilities to competitive advantage: An exploratory study in China", Inf Syst Front, 12, 239-255, 2010.

[42] Arvidssona, V., Holmströma, J. and Lyytinend, K. "Information systems use as strategy practice: A multi-dimensional view of strategic information system implementation and use", The Journal of Strategic Information Systems, Volume 23, Issue 1, Pp. 45–61, 2014

[43] McCredie, J. and D. Updegrove "Enterprise System Implementations: Lessons from the Trenches", Cause/Effect, Vol.2, No.4 , pp. 1-10, 1999.

[44] Ishak N. K., Mutum D., Ghazali E., and Fan K. C. "An exploratory study of the implementation of customer relationship management by Malaysian automobile distributors", International Business and Entrepreneurship Development, Vol.3, No.1/2, pp. 41 – 56, 2006

[45] Gu, Ja-Whan and Jung, Ho-Won "The effects of IS resources, capabilities, and qualities on organizational performance: An integrated approach", Volume 50, Issues 2–3, Pages 87–97, 2013.

[46] Eraqi, I. M. "IT as a Means for Enhancing Competitive Advantage" Anatolia: An International Journal of Tourism and Hospitality Research", Vol. 16, No. 2, pp. 1-18, 2005.

[47] Bruque, S., Moyano, J.; Vargas, A., and Hernández, M. "Ownership Structure, Technological Endowment and Competitive Advantage: Do Democracy and Business Fit?", Technology Analysis & Strategic Management, Vol. 15, No.1, pp. 65-79, 2003.

[48] Andam, R. E-Commerce and E-Business. Eastern task force UNDP, 2003.

[49] Merisavo, M. "The Effects of Digital Marketing Communications on Customers' Loyalty: An Integrative Model and Research Propositions", University of Helsinki working paper series, No. W400, 2006.

[50] Boadi, A R., and Shaik, G. A. "M-commerce breaking through developing countries: The role of M-commerce in wealth creation and economic growth in developing countries", Unpublished Master thesis in computer systems science continuation courses, Lulea University of Technology, 2006.

[51] Arunthari, S. "Information Technology adoption by companies in Thailand: a study of Enterprise Resource Planning System usage", Unpublished Doctoral dissertation, University of Wollongong, 2005.

[52] Tallon, P. P. "Does IT Pay to Focus? An Analysis of ITS Business Value under Single and Multi-focused Business Strategies", Journal of Strategic Information Systems (JSIS), No.16, Vol. 3, pp.278-300, 2007.

[53] Kearns , G. and Lederer , A. "The effect of strategic alignment on the use of IS-based resources for competitive advantage", Systems, Vol.9, No. 4, pp. 265-293, 2000.

[54] Spanos, E, Y., and Lioukas, S. "An examination into the causal logic of rent generation: Contrasting Porter's competitive strategy framework and the resource-based perspective", Strategic Management Journal, John Wiley and Sons, Inc, Vol. 22, No. 10, pp. 907–934, 2001.

[55] Kerlinger, F. N. and Lee, H. B. Foundations of behavioral research, 4rd ed., New York: Wadsworth Publishing, 1999.

[56] Hinkin, T. R. "A Brief Tutorial on the Development of Measures for Use in Survey Questionnaires", Organizational Research Methods, Vol.1, No. 1, pp.104-121, 1998.

[57] Nunnally, J.C. Psychometric theory. New York: McGraw-Hill, 1978.

[58] Andrew, M. W. "Mobile Banking in Developing Countries: a case study on Kenya", Vaasan Ammattikorkeakoulu, University of Applied Sciences, Degree Programmer of Information Technology, 2009.

[59] Jaworski, B.J., Kohli, A.K., Sahay, A. "Market-driven Versus Driving Markets", Journal of the Academy of Marketing Science Vol. 28, No.1, pp. 28, 45–54, 2000.

[60] Laudon, K. and Laudon, J. Management information systems: organization and technology in the networked enterprise, 6th ed., London: Prentice Hall, 2000.

[61] NCT report, Sudan, 2008. Avaliable at: http://www.ntc.gov.sd

[62] Turban, E., Leidner, D., Mclean M., and Wetherbe, J. Information Technology for Management. Transforming Organizations in the Digital Economy, Fourth Edition. New York: John Wiley and Sons, Inc, 2006.

[63] Zhenyu ,Y. "Toward Digital Dynamic Capabilities - A Theoretical Exploration", International Journal of Electronic Commerce Studies Vol.2, No.1 , pp.1-18, 2011.

[64] Barney, J. "Firm resources and sustained competitive advantage", Journal of Management, Vol. 17, No. 1, pp. 99-120, 1991.

[65] Yin, G. and Yang, B. "The Construction Of Firm's It Capability And Its Impact On It Assimilation: An Empirical Investigation In China", Service Science, Vol. 2, No. 2,pp11-20, 2001.

A New Artificial Neural Networks Approach for Diagnosing Diabetes Disease Type II

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***Abstract*—Diabetes is one of the major health problems as it causes physical disability and even death in people. Therefore, to diagnose this dangerous disease better, methods with minimum error rate must be used. Different models of artificial neural networks have the capability to diagnose this disease with minimum error. Hence, in this paper we have used probabilistic artificial neural networks for an approach to diagnose diabetes disease type II. We took advantage of Pima Indians Diabetes dataset with 768 samples in our experiments. According to this dataset, PNN is implemented in MATLAB. Furthermore, maximizing accuracy of diagnosing the Diabetes disease type II in training and testing the Pima Indians Diabetes dataset is the performance measure in this paper. Finally, we concluded that training accuracy and testing accuracy of the proposed method is 89.56% and 81.49%, respectively.**

***Keywords*—diabetes type 2; probabilistic artificial neural networks; data mining; mean squares error; Naive Bayes**

I. INTRODUCTION

Diabetes is one of the most common diseases in the world. This disease is divided into two types: type 1 and type 2. In this paper, we focused on diagnosing diabetes type 2 using PPN. The causes of diabetes include genetics, unsuitable diet, lack of physical activity, obesity, etc. Postponing the diagnosis and treatment of type 2 diabetic patients leads to some major issues such as heart attacks, strokes, blindness, and kidney failure, and in some cases it causes Mutilation [1,2,3,4]. Indeed one of the most important problems in the medical world is timely and exact diagnosis of diseases. Generally, diagnosis is a complex task which requires high skill and experience. Timely diagnosis and specialized medical care of patients can reduce issues of patients, as well as treatment costs in other therapeutic courses [5,6]. A lot of diverse solutions have been proposed for different diseases up to now. Artificial neural networks are the most common solution. They are a branch of artificial intelligence and accepted as a novel technology in computer science. Artificial neural network is a technique which tries to simulate behavior of the neurons in humans' brain. This technique has had a wide usage in recent years. Diagnosis, estimation, and prediction are main applications of artificial neural networks. Artificial neural networks with their own data try to determine if a person is patient or not. With diverse models of ANNs it is possible to perform the diagnosis task on different diseases, so we can address the issue of identifying the disease at the first phase using different models of ANNs with reduced human related errors. This way, the patient can prevent irreversible complications and save his health. In addition, in recent years ANNs applied in all fields of medical sciences, and have been accepted by physician for both identifying the diseases and patient treatments [6, 7]. When using ANNs for identifying diseases, the aim is to achieve a high accuracy rate, and quality of diagnosis depends on training and testing a data set [7]. Before starting the task of diagnosis, models of ANNs must be trained according to patient's data sets. After training and testing, the patient's data sets using models of ANNs, the way for achieving high accuracy and minimum error rate is provided [7, 8]. In this paper we aims at achieving maximum accuracy rate in training and testing phases of diagnosing the diabetes disease type 2 using PPN models. Some advantages of PNN include its novelty for identifying diabetes type 2 instead of using traditional approaches with human error, as it reduces the human costs and has made a major contribution to medical science. To this end, a data set named Pima Indians Diabetes with 768 data samples is used, such that each sample includes certain features. By using these 768 data sample, we train the PNN model. Furthermore, we implemented the model of PNN for diagnosing diabetes diseases in MATLAB.

The remainder of this paper is organized as follows. We first summarize some related works in Section 2. We study and discuss the Pima Indians Diabetes data set in section as well as the proposed PNN model for diagnosing diabetes type 2 based on both training and testing Pima Indians Diabetes. Then we investigate and compare the related works on identifying diabetes type 2 using PNN model in training and testing phases in section 4. Finally, in section 5 we conclude this paper and suggest some future works in the area of diabetes type 2 diagnoses.

II. RELATED WORKS

Significant research in the context of diagnosis of diabetes using artificial neural networks and data mining techniques have been done till now. In this section we study some of these researches, and then compare them with the accuracy of training and testing the process of diagnosing diabetes type 2.

Sa'di et.al. [4] used data mining techniques such as Naïve Bayes, J48 and Radial Basis Function Artificial Neural Networks for diagnosing diabetes type 2. They took advantage of a data set with 768 data samples, 230 of them selected for test phase. Naive Bayes algorithm with 76.95% accuracy outperformed J48 and RBF with 76.52% and 74.34% accuracies, respectively.

Authors in [9] use back-propagation multi-layer artificial neural networks for identifying diabetes type2. Back-propagation is a supervised learning algorithm and is based on error correction. Back-propagation compares the computed output value with the real value and tries to modify the weights according to the calculated error, such that after each round, the size of obtained error be less than the value in the previous round. In order to train Back-propagation, we used Sigmoid function. Also, we used Pima Indians Diabetes in our evaluations. This data set contains 768 data sample, 568 of which were used as training set and 268 as testing set. Furthermore, back-propagation multi-layer artificial neural networks consists of 8 neurons in input layer, 6 neurons in hidden layer, and 2 neurons in output layer. Note that input layer neurons are those 8 features which are used in dataset. The achieved diagnosis accuracy after 2000 rounds of dataset training becomes 82%. Hence, Back-propagation algorithm has the highest accuracy compared to BSS, EM, KNN, C4.5 approaches.

Al-Rofiyee, *et al.* [10] use multilayer perceptron (MLP) artificial neural networks for identifying diabetes type 2. There are a lot of problems which are not linearly separable. Diabetes diagnosis is one of these problems, because diagnosing diabetes disease using single layer perceptron is wrong and there is no right answer for it. In order for artificial neural network to learn non-linear, it should designed as multi-layer. Each layer can contain different number of neurons. Therefore, they used multi-layer perceptron for diagnosing diabetes type 2. Multi-layer perceptron networks consist of an input layer, several hidden layers and an output layer. In this paper, MLP model includes one input layer with feature of Pima Indians Diabetes, hidden layer with certain neurons and an output layer which has the responsibility of diagnosis. About 20% of data are used as training set, 60% as testing set and finally 20% are used as application set. Time and number of neurons in hidden layer of MLP model are two important parameters. Finally, highest diagnosis accuracy in training phase using MLP model with maximum time and minimum number of neurons in hidden layer in comparing with same times and neuron numbers was 97.61%.

In [11], authors use a dataset with 250 data samples for diagnosing diabetes disease. Each of these 250 data samples consist of 27 features. These features include blood pressure, creatine, pH urine, and fasting blood sugar. Also, the average age of patients in their dataset is between 25 and 78 years. Multi-layer feed-forward artificial neural networks with back-propagation are used for diagnosis. Three training functions namely BFGS Quasi-Newton, Bayesian Regulation and Levenberg-Marquardt are applied in back-propagation algorithm. Finally, back-propagation with Bayesian Regulation function achieved 88.8% of diagnosing accuracy which performed better than BFGS Quasi-Newton and Levenberg-Marquardt functions. Furthermore, in [2], data mining techniques with Pima Indians Diabetes dataset is used for identifying diabetes. The applied data mining techniques include SVM, KNN, C4.5 and artificial neural networks with input, hidden and output layers. Finally, artificial neural networks have a higher diagnosing accuracy compared to other data mining techniques.

In [12], authors use general regression neural networks and Pima Indians Diabetes for identifying diabetes type 2. GRNN model in this paper is assumed to be a four-layer model; one input layer with 8 features from Pima Indians Diabetes, two layers which have 32 and 16 neurons, respectively. Finally, output layer has one neuron. This neuron determines if a person is patient or not. It is used for classification of Pima Indians Diabetes dataset into healthy and patient classes. The above mentioned dataset with 576 data sample as training set and 192 data set as testing set is used for training and testing processes. The accuracy rate achieved for training and testing phases are 82.99% and 80.21%, respectively. Training phase for diagnosing diabetes type 2 obtained a higher value of accuracy compared to other works studied in this paper.

III. PROPOSED MODEL

In order to identify diabetes and other diseases such as heart diseases [13, 14], Parkinson's disease [15, 16], and lung cancer, having a data set is very important and necessary, since ANNs are trained by these data sets and they can perform the diagnosis task. Therefore, in this paper, we used Pima Indians Diabetes [19] with 768 data sample for diagnosing diabetes type 2. This data set consists of 9 features for each data sample. Table (1) shows these 9 features.

According to Table 1, there are 9 features for each data sample. The first 8 features are inputs, and the last feature is the only output. In order to classify the 768 data samples, 9th feature is used as it is classified into two classes: class zero (healthy) and class 1 (patient).

TABLE I. FEATURES OF PIMA INDIANS DIABETES FOR DIAGNOSING DIABETES DISEASE TYPE 2 [19]

No. Attributes	**Attributes**	**Descriptions and Attribute values**
1	Number of Times Pregnant (NTP)	Numerical values
2	Plasma Glucose Concentration (PGC)	Numerical values
3	Diastolic Blood Pressure (DBP)	Numerical values in (mm Hg)
4	Triceps Skin Fold Thickness (TSFT)	Numerical values in mm
5	2-Hour Serum Insulin (2-HSI)	Numerical values in (mu U/ml)
6	Body Mass Index (BMI)	Numerical values in (weight in kg/(height in m)^2)
7	Diabetes Pedigree Function (DPF)	Numerical value
8	Age	Numerical values
9	Diagnosis of type 2 diabetes disease	Yes=1 No=0

TABLE II. STATISTICAL ANALYSIS FOR MEAN AND STANDARD DEVIATION IN PIMA INDIANS DIABETES DATA SET [19]

No. of Feature	Feature Name	Mean	Standard Deviation
1	Number of times pregnant	3.8	3.4
2	Plasma glucose concentration	120.9	32.0
3	Diastolic blood pressure	69.1	19.4
4	Triceps skin fold thickness	20.5	16.0
5	2-Hour serum i insulin	79.8	115.2
6	Body mass index	32.0	7.9
7	Diabetes pedigree function	0.5	0.3
8	Age	33.2	11.8

The average age of this data set is between 21 and 81 years.

In addition, according to Pima Indians Diabetes data set which has 768 data samples, Table 2 shows the Mean and standard deviation of the data set.

Nowadays, artificial neural networks can be used in all industries. Artificial neural network consists of a set of neurons which are characterized by special arrangement. The main parts of an artificial neural network are neurons and connections between them. Neurons are conjunct processing elements which work together to solve a problem [8, 20, 21]. Learning capability is the main advantage of ANNs, since an ANN will adjust in learning process for information classification, and identifying patterns [18, 20]. ANNs with a high ability to diagnose diseases help in medicine sciences. The reasons ANNs are used in medicine include high accuracy of physicians in their decision makings, increase confidence, creating medicine tools, reduce costs, etc. [22]. ANNs consist of different models such as PNN, MLP, RBF, and GRNN [8, 20, 21]. In this paper, we use PNN model for diagnosing diabetes type 2. PNN model has a parallel structure and is special for information classification. In contrast to other ANNs such as MLP, PNN has a higher speed in training the data, and it finds answers faster than MLP [6, 20, 21]. This model consists of 3 layers: input layer, hidden layer, and output (competitive) layer. The hidden layer is also called radial base layer, as PNN model is a mode of RBF model. Hidden layer units uses Gaussian transmission function, and number of neurons in this layer is same as number of rounds in training data set. This layer computes distance between input vector and training inputs, and provides a vector where its elements determine the distance between the input and training inputs. Hidden layer generates a vector of probabilities as output. Finally, this layer selects probability values from probabilities vector and generates value 1 for it and 0 for other probabilities [6, 20, 21]. Gaussian transmission function which is used in hidden layer calculated as follows [20, 21]:

$$D_{t,r}(P) = \frac{1}{(2\pi\sigma^{2})} \exp\left(-\frac{\left\| P - P_{t,r} \right\|^{2}}{2\sigma^{2}} \right) \qquad (0)$$

Where P (P1, P2,…, Pn) is the input vector which consists n variables. Neurons of hidden layer are divided into t groups, each group includes one class. r is the neuron in group t which is calculated using Gaussian function. σ is a constant that increases training and testing accuracy and is used by neurons of hidden layer. Sum of neurons in a group of t is computed using equation (2) [8, 20, 21].

$$G_t(P) = \sum_{r=1}^{Z_t} W_{tr} D_{t,r}(P), \quad T \in \{1,...,T\}, \qquad (0)$$

Where, Z_t is the number of neurons of the pattern in a class. W_{tr} is the coefficients of weights, where $G_t(P)$ generate 1 for maximum of the probability values. Classified pattern vector P belongs to the class which relates to sum unit with maximum output value and is calculated as follows [8, 20, 21].

$$Y_r = \begin{cases} 1 & if \quad S_r \; is \max of \; \{G_1, G_2\} \\ 0 & else \end{cases} \qquad (0)$$

Training in ANNs is a process where ANN learns to identify the pattern in its inputs which has the form of a training data set. In fact, ANN adopts (adjust) its weights in response to the inputs at the training phase, such that the real output of ANN converges to the desired output. Once actual output of ANN becomes the desired output, the process of training the networks terminates, such that ANN leads to the least error rate [5, 6, 8, 20, 21]. After training the ANN using training data until achieving minimum error rate, other data which have no effects in training process feeds to the ANN as testing inputs. Then ANN's response is compared with the desired response and accordingly we get a trained network. If ANN responds in a right way to when it is tested, the training process terminates, otherwise ANN training starts again. Lastly, when the program passes the training phase, and generates the right response on every input, then it is obvious that ANN's weights adjusted in a right way. Therefore, from now on these values are used for diagnosis and prediction tasks [5, 6, 8, 20, 21]. Additionally, Mean Square Error (MSE) is the performance index in the process of training PNN model. MSE reduces amount of computations and memory requirements for computational tasks, and it is trying to minimize the MSE value for training data [20,21]. Hence, number of neurons in hidden layer according to MSE is same as number of rounds at the last desired execution of PNN model in training process. For computing MES equation (4) is used [20, 21].

$$MSE = \frac{1}{Q} \sum_{k=1}^{1} \left(t(k) - a(k) \right)^{2} \qquad (0)$$

Where a(k) is the real output of the network, t(k) is the expected output and Q is number of rounds. In this paper we used Pima Indians Diabetes data set which consist 768 data samples. 90% of data samples, that is, 691 of them used for training, and 10%, that is, 77 out of 768 data samples used for testing. After training and testing the data using PNN model, if a right output generates, it used as the values for diagnosing diabetes disease type 2. Figure 1 illustrates PNN model scheme for diagnosing diabetes type 2.

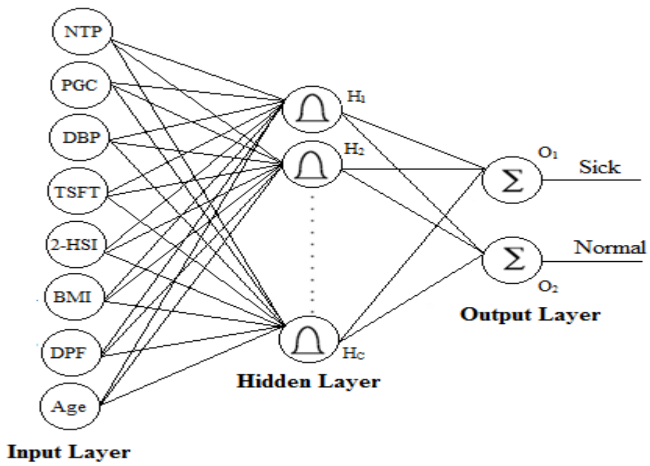

Fig. 1. Proposed PNN model scheme for diagnosing diabetes type 2

As shown in Figure 1, at input layer, the number of neurons is same as 8 features in Pima Indians Diabetes data set which showed in Table 1. As shown in Table 1 each feature's name has been written in every neuron. Number of neurons in hidden layer is denoted by Hc. Hc is same as number of training data sets. In the output layer, the number of neurons equals to 2 defined classes, that is, class 1 (sick) and class 2 (normal). Furthermore, we used MATLAB to implement PNN model for diagnosing diabetes type 2. Finally, according to the proposed model shown in Figure 1, Pima Indians Diabetes dataset, and number of samples for training and testing 768 data samples, achieved outputs of Table 3 and Figure 2 for minimizing mean squares error during the process of data training, and Figure 3 which shows training accuracy and testing accuracy.

TABLE III. MEAN SQUARES ERROR IN EACH ROUND FOR DIFFERENT VALUES OF NEURONS OF HIDDEN LAYER IN PNN MODEL

No. of neurons in hidden layer	MSE
0	0.898927
25	0.522076
50	0.490339
75	0.459006
100	0.42791
125	0.396591
150	0.374956
175	0.314095
200	0.299721

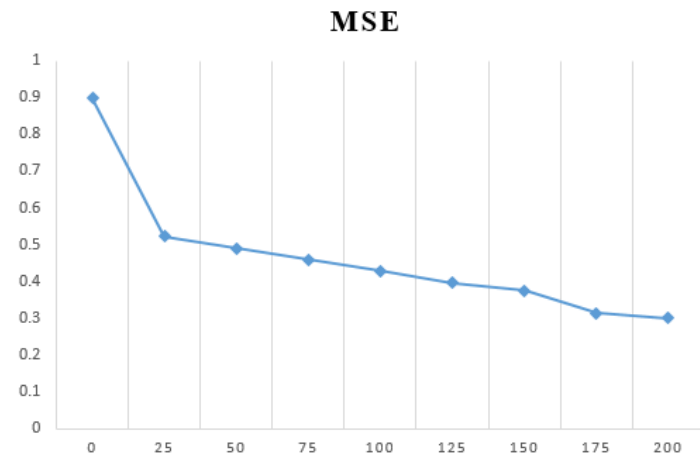

Fig. 2. Decreasing diagram of mean squares error for different values of neurons of hidden layer in PNN model

According to Table 3 and Figure 2, after 200 rounds, achieve its lowest possible value, 0.299721. Number of rounds is same as number of neurons in hidden layer. Number of neurons in hidden layer in each round increases by 25 units, and this continues until 200 neurons, such that mean squares error reaches its lowest possible value.

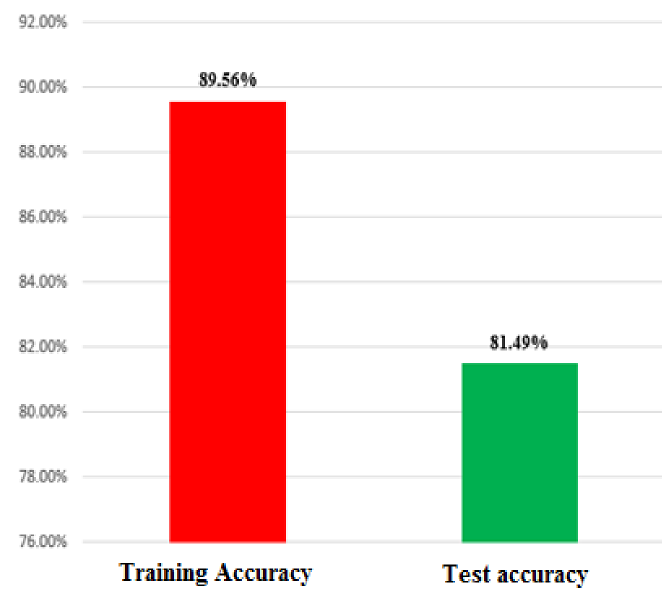

Fig. 3. Accuracy of diabetes type 2 diagnosis in training and testing Pima Indians Diabetes data set.

According to Figure 3 and Pima Indians Diabetes data set which consists 768 data samples, obtained accuracy rate of training phase for 90% of data (691 data samples) is 89.56%. Furthermore, obtained accuracy rate of testing phase for 10% of data (61 data samples) is 81.49%. Therefore, training the data has a higher accuracy rate than testing phase. However, both training and testing measures on Pima Indians Diabetes data sets using PNN model achieved a good accuracy rate.

IV. Discussion and Evaluation

In this section, we discuss and investigate results of diagnosing accuracy in training and testing phases as well as studies presented in section 2. Figures 4 and 5 show these comparisons.

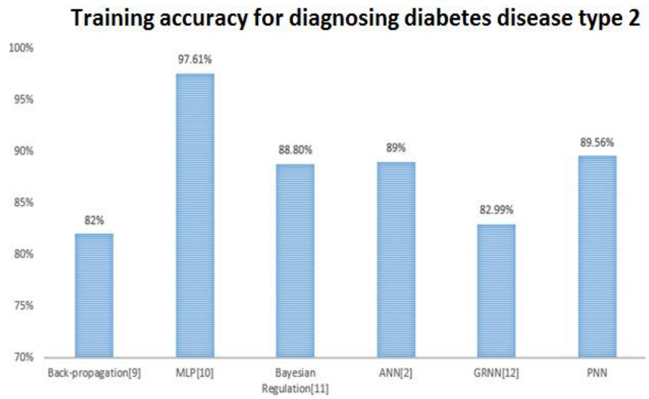

Fig. 4. Comparison of training accuracy of diagnosing diabetes type 2 between proposed and other approaches in training phase

As shown in Figure 4, all traditional studies with Pima Indians Diabetes data set except Bayesian Regulation [11] perform the task of identifying diabetes type 2. It is obvious that our method using PNN model outperforms other models such as back-propagation[9]‹Bayesian Regulation[11], ANN[2], and GRNN[12] in terms of accuracy of diagnosing diabetes type 2. MLP [10] is the only model which has a higher accuracy than our PNN model. Back-propagation [9] with 82% accuracy is the worst approach. This value is close to the 82.99% accuracy which belongs to GRNN [12]. Furthermore, MLP [10] with 97.61% accuracy is the best approach in training phase. Also, accuracy of ANN [2] and PNN are too close to each other.

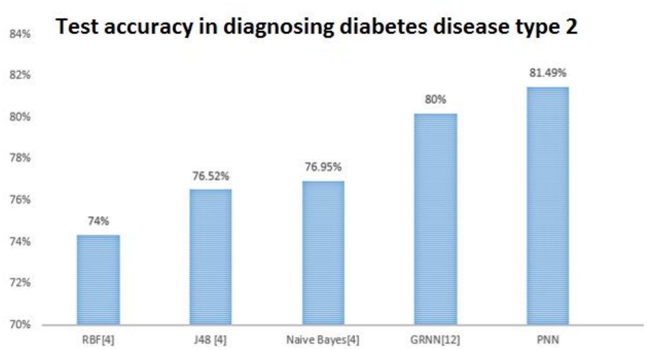

Fig. 5. Comparison of test accuracy of diagnosing diabetes type 2 between proposed and other approaches in testing phase

As shown in Figure 4, all traditional studies with Pima Indians Diabetes data set perform the task of identifying diabetes type 2. It is concluded that PNN model has the highest accuracy for diagnosing diabetes type 2 compared to other models. RBF [4] with 74% accuracy has the worst accuracy rate among the compared models. J48 [4], Naïve Bayses [4] are too close to each other.

V. Conclusion and Future Work

Advances in information and communication technologies leads to the use of artificial intelligence technologies in various fields including medicine science. By using artificial neural networks, we can design and implement the complex medical processes as software. These software systems in turn are effective for different fields of medicine sciences such as diagnosis, treatment and to help Surgeons, physicians and the public. These systems can be implemented in different scales in a parallel and distributed manner. In general, ANNs are parallel processing systems which are used for identifying complex patterns among data. Therefore, in this paper PNNs are applied to identifying diabetes disease type 2. We implemented the PNN model in MATLAB. The Pima Indians Diabetes data set was used for diagnosing diabetes type 2, which consists 768 data samples with 9 features. 90% of these 768 samples are used as training set and 10% used as testing set. The method achieved 89.56% of diagnosis accuracy in training phase, and 81.49% in test phase. Both training and testing measures could identify the diabetes disease type 2 with a good accuracy. As a future work, we will use the combination of fuzzy and artificial neural networks or combination of genetic and artificial neural networks for diagnosing diabetes type 2.

References

[1] M. Khashei, S. Eftekhari, J. Parvizian, "Diagnosing Diabetes Type II Using a Soft Intelligent Binary lassification Model", *Review of Bioinformatics and Biometrics (RBB),* Vol. 1, Issue 1,(2012), pp.9-23.

[2] M. Durairaj, G. Kalaiselvi, "Prediction Of Diabetes Using Soft Computing Techniques- A Survey", *international journal of scientific & technology research,* vol. 4, issue 03,(2015), pp.190-192.

[3] Type 2 Diabetes*: The Basics*, (2016), http://www.webmd.com/diabetes/type-2-diabetes-guide/type-2-diabetes.

[4] S. Sa'di, A. Maleki, R. Hashemi, Z. Panbechi, K. Chalabi, "Comparison of Data Mining Algorithms in the Diagnosis of Type Ii Diabetes*", International Journal on Computational Science & Applications (IJCSA),* Vol.5, No.5,(2015), pp. 1-12.

[5] B. Zebardast, R. Rashidi, T. Hasanpour, F. S. Gharehchopogh, "Artificial neural network models for diagnosing heart disease: a brief review", *International Journal of Academic Research*, Vol.6, Issue 3,(2014), pp.73-78.

[6] S. Sa'di, R. Hashemi, A. Abdollapour, K. Chalabi, M. A. Salamat, "A Novel Probabilistic Artificial Neural Networks Approach for Diagnosing Heart Disease", *International Journal in Foundations of Computer Science & Technology (IJFCST)*, Vol.5, No.6, (2015), pp.47-53.

[7] F.S. Gharehchopogh, Z.A. Khalifelu, "Neural Network Application in Diagnosis of Patient: A Case Study*", IEEE, International Conference on Computer Networks and Information Technology(ICCNIT2011), Abbottabad, Pakistan*, (2011), pp. 245-249.

[8] H. Demuth, M. Beale, "Neural Network Toolbox for Use with MATLAB", User's Guide, Version 4, The MathWorks, Inc. 3 Apple Hill Drive Natick, MA 01760-2098,840 pages, 2002.

[9] E. O. Olaniyi, K. Adnan, "Onset Diabetes Diagnosis Using Artificial Neural Network*", International Journal of Scientific & Engineering Research*, vol.5, issue 10,(2014), pp. 754-759.

[10] A. Al-Rofiyee, M. Al-Nowiser, N. Al-Mufadi, M. A. AL-Hagery, "using prediction methods in data mining for diabetes diagnosis", *posters*, (2014).

[11] S. Kumar, A. Kumaravel, "Diabetes Diagnosis using Artificial Neural Network", *international journal of engineering sciences & research technology*, Vol.2, No.6,(2013), pp. 1642-1644.

[12] K. Kayaer, T. Yildirim, "Medical Diagnosis on Pima Indian Diabetes Using General Regression Neural Networks", (2003).

[13] R. Raut, S. V. Dudul, “intelligent Diagnosis of Heart Diseases using Neural Network Approach*”, International Journal of Computer Applications,* Vol.1, No.2,(2010), pp. 97-102.

[14] A. T. sayad, P. P. halkarnikar, “diagnosis of heart disease using neural network approach*”, International Journal of Advances in Science Engineering and Technology*, Vol.2, No.3, (2014), pp.88-92.

[15] S. Bhande, R. Rau, “Parkinson Diagnosis using Neural Network: a Survey”, *International Journal of Innovative Research in Science, Engineering and Technology*, Vol. 2, Issue 9, (2013) pp. 4843-4846.

[16] M. Can, “Neural Networks to Diagnose the Parkinson’s disease*”, southeast europe journal of soft computing*, Vol.2, No.1, (2013), pp.68-75.

[17] J .Kuruvilla, K. Gunavathi, “Lung cancer classification using neural networks for CT images, “*Computer Methods and Programs in Biomedicine*”, Vol. 113, No.1, (2014), pp. 202-209.

[18] M .A. Hussain, T .M. Ansari, P .S. Gawas, N .N .Chowdhury, “Lung Cancer Detection Using Artificial Neural Network & Fuzzy Clustering”, “*International Journal of Advanced Research in Computer and Communication Engineering”*, Vol. 4, No.3, (2015), pp.360-363.

[19] Pima Indians Diabetes Data Set, https://archive.ics.uci.edu/ml/datasets/Pima+Indians+Diabetes [Last Available: February 2016].

[20] S. N. Sivanandam, S. N Deepa, “Introduction to Neural Networks Using Matlab 6.0”, *Tata McGraw-Hill Education*, ISBN: 978-0-07-059112-7, (2006), 656 pages.

[21] Neural network Toolbox, http://www.mathworks.com/products/neural-network/?s_tid=srchtitle [Last Available: February 2016].

[22] S .Moein, “Medical Diagnosis Using Artificial Neural Networks”, *Part of the Research Essentials Collection*, DOI: 10.4018/978-1-4666-6146-2, 310 pages, 2014.

A Hybrid Algorithm Based on Firefly Algorithm and Differential Evolution for Global Optimization

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Abstract—**In this paper, a new and an effective combination of two metaheuristic algorithms, namely Firefly Algorithm and the Differential evolution, has been proposed. This hybridization called as HFADE, consists of two phases of Differential Evolution (DE) and Firefly Algorithm (FA). Firefly algorithm is the nature-inspired algorithm which has its roots in the light intensity attraction process of firefly in the nature. Differential evolution is an Evolutionary Algorithm that uses the evolutionary operators like selection, recombination and mutation. FA and DE together are effective and powerful algorithms but FA algorithm depends on random directions for search which led into retardation in finding the best solution and DE needs more iteration to find proper solution. As a result, this proposed method has been designed to cover each algorithm deficiencies so as to make them more suitable for optimization in real world domain. To obtain the required results, the experiment on a set of benchmark functions was performed and findings showed that HFADE is a more preferable and effective method in solving the high-dimensional functions.**

Keywords—Differential Evolution; Firefly Algorithm; Global optimization; Hybrid algorithm

I. INTRODUCTION

One of the affective methods in finding the best solution in numerical problems is the Optimization technique. In optimization, only a few solutions are considered the best which are called as the goal. Classical optimization techniques have some deficiencies on solving the complex optimization problems. These deficiencies are primarily interdependent on their inherent search systems. These classical optimization methods are strongly under effects of choosing proper objectives, constraints functions and type of variables. They also do not grant a universal result approach that can be used to solve problems where various type of variables, objective and constraint functions, are used [1]. For covering these deficiencies, a new method with the name of metaheuristic was designed, which is mainly originated from artificial intelligence research that developed by researchers [2]. A metaheuristic is an algorithm designed for solving the various types of hard optimization problems without having to fully accommodate to each problem. The Greek word meta indicates that these methods are higher-level heuristics. The primary features of metaheurisitc methods are as follows: they are nature-inspired (meaning that they have originated from nature physics, behavior and etc); stochastic components are one of the inseparable parts of these methods (involving random variables); they arent gradient base method and dont use them; at the beginning of program, they have several parameters which needs to adjusts properly. Metaheuristic algorithms combine various intelligent procedures and guide basic heuristic methods [3]. These algorithms are inspired from different things such as natural phenomena, natural selections and social behaviors and applied in solving the optimization problems. Examples of the recently metaheurtistc algorithms are Vortex search [4], WOA (whale optimization algorithm) [5], MBA (mine blast algorithm) [6], WCA (water cycle algorithm) [10], and SFS (stochastic fractal search) [8].

The Firefly algorithm (FA) [9] is one of the nature-inspired algorithms presented to perform global optimization in complex search spaces. In fact, it uses the act of firefly in nature and simulates behave of attraction to the flashing lights of fireflies.

One of the population based metaheuristic algorithms is the Differential evolution algorithm (DE) which is modeled on Darwins evolutionary principle of Survival of the Fittest [10]. DE, like the Genetic algorithms, benefits from the Natural Selection Theory and uses its operators like the crossover, mutation and selection to create the new population for the next generation. Over the last decades, experiments on the DE algorithm have proven that it is the simplest algorithm which shows the best performance in metaheuristic algorithm for global optimization and in real parameter optimization. The most important difference between GA and DE is that DE uses distance and direction information from the current population to guide the search process.

Hybridization of DE with other algorithms has been investigated in many studies. DE-VNS [11]is a new type of hybrid method which combines two well-known metaheuristic approaches: Differential Evolution (DE) and Variable Neighborhood Search (VNS) [12],which has, in the last decade, attracted considerable attention in both academic circles and among practitioners. A promising new nature-inspired algorithm known as FA was recently proposed and has gained more attention in the research literature. The ACOFA [13] is the new hybridization for FA and ACO [14] algorithm. This hybrid algorithm has been designed to solve unconstrained optimization problems and FA works as a local search to refine the positions found by the ants. In this paper, we will combine DE and FA global optimization algorithms, and propose the novel hybrid algorithm based on these algorithms which are jointly called as HFADE. As DE has Operators like crossover and mutation, this could provide more variant population for FA which could help in finding more lighter fireflys algorithms.

In the real world, many problems have been porposed and optimization problems are one of them [15]. The optimization problems are single or multi-objective. The multi-objective is the problem with more than one objective function (m¿1) and single objective is a problem with one objective function (m=1). The main goal in this procedure is to seek the global minimum or maximum. The function may have more than one minimum or maximum which is called as the local, but only one of them is the global maximum or minimum. The point x* is the global minimum if f(x*)≤f(x) for all the x in the searching space S. Optimization problem may consist of one or more mathematical functions which need to be optimized. The general form of the optimization problem is indicated in Eq. (1).

$$minimize F\left(f_1(x),\ldots,f_m(x)\right), \qquad x = (x_1,\ldots,x_n) \in S \tag{1}$$

Where n is the decision variables, m is the number of objectives, x is decision vector and S is searching space. If the problem has one objective function (m=1), then it should be indicated as Eq. (2).

$$minimize f(x), \qquad x = (x_1,\ldots,x_n) \in S \tag{2}$$

The rest of the paper is organized as follows: Section 2 illustrates the DE and FA algorithms, and section 3 discusses the HFADE algorithm, its parameters and boundary control. Section 4 presents 26 benchmark test functions applied for the experiments. Finally, the last section presents the concluding remarks.

II. Firefly Algorithm and Differential Evolution

A. Firefly Algorithm (FA)

Firefly algorithm was introduced by X.S Yang for the first time in 2007 [9]. This algorithm has been inspired from the fireflys behavior and its attraction to the light. It has more similarity to PSO [16]and therefore implementation for this algorithm is much easier. Flashing insects at nights are fireflies and they gather together when they have started the flashing. Each firefly releases small rhythmic light flashes which has a light intensity attraction I and this light will decrease by distance r increment. So, each firefly attracts to the other firefly which is lighter and nearer to them. Intensity of light in the firefly depicts its fitness value, meaning the lighter the Firefly, the more fitness one has over the other. This light-intensity attractiveness of firefly is demonstrated by I in the firefly algorithm.

1) Attractiveness and Light Intensity: Each firefly has position in searching space and the light intensity for this firefly in distance r is I(r) which is fitness value for distance r. The light intensity decrease base on the square of distance. So, the I (r) varies according to the well-known inverse square law.

$$I(r) = \frac{I_s}{r^2} \tag{3}$$

Fireflies attractiveness is proportional to the I(r) seen by surrounding fireflies can be defined as

$$\beta_0 e^{-\gamma r^2} \tag{4}$$

where γ is the light absorption coefficient.

2) Distance: The distance between fireflies i and j ($r_{i,j}$) is computed by euclidean distance formulation for d dimensional position x . This distance calculated as follow:

$$r_{i,j} = \sqrt{\sum_{k=1}^{d} (x_{i,k} - x_{j,k})^2} \tag{5}$$

Movement: The new position for firefly calculated by Eq. (6). In this equation first term is previous position and second term is used for determining the attractiveness() of a firefly (attractive firefly), towards the attractive neighboring fireflies and third term causes movement in random direction toward the brighter firefly xi.

$$x_i = x_i + \beta_0 e^{-\gamma r^2}(x_j - x_i) + a\varepsilon_i \tag{6}$$

if the firefly i is not brighter than firefly 'j' then the algorithm will perform random walk with following formulation:

$$x_i = x_i + \alpha\left(rand - 1/2\right) \tag{7}$$

where the coefficient α is a randomization variable, and '*rand*' is a random real number between interval [0 1].

Firefly algorithm is explained as follows:

Fireflyalgorithm

```
Generatetheinitialpopulationrandomly.
Calculatethefitnessofinitialpopulationbasedonlightintensityoffireflies.
While ( criterion )
   for i=1,2,...,n  do (nfirefly )
   for j=1,2,...,n  do.
      Calculate β usingEq.(4).
      Distancebetweentwofirefliesiscalculatedusing Eq.(5).
      If (I(i) < I(j)) then
        Fireflyiismovedtowardsfireflyjusing Eq.(6).
          Determinenewsolutions..
      else
        Fireflyiismovedrandomlytowardsjusing Eq.(7).
     endif
   endforj
   endfori
endwhile
Sortthefirefliesaccordingtolightintensityvaluesofthenewsolution.
```

B. Differential Evolution (DE)

Most of the metaheuristic algorithms start the searching space with initial population. These methods are population-based metaheuristic algorithms and DE is one of them [10]. The DE is simple to implement and requires a minimum parameter to be adjusted so as to make it the best for combinatorial optimization. It requires to be adjusted based on three parameters which are F, CR and N (population size). Parameter F is the weighting coefficient that is used to generate new trial solutions and CR is the crossover probability which is used to specify a rate of crossover. It has been argued that the DE algorithm is highly under the effects of choosing proper values for the CR and F, and hence, changing the proper amounts of F and CR during algorithm execution can boost its efficiency. The mutation plays the most important role in the DE algorithm, and as a result, it is one of the main parts of the DE. The mutation equation is as follows:

$$Xnew_i = a_i + F \times \left(b_i - c_i\right) \tag{8}$$

here a, b and c are random selected agents from population and *i* is the index from dimension *d*. The Xnew is the new agent which is created from the mutation. The DE algorithm is described as follows:

DEalgorithm

```
InitialeachagentXinpopulationwithrandompositioninsearchingspace.
CalculatethefitnessofeachagentXinpopulation.
While ( criterion)
    for eachagentXin  X1...Xn  populationdo
      selectthreeagenta,bandcrandomlyfrompopulation( a ≠ b ≠ c ≠ X )
      selectrandomindexifromi ∈ 1,...,d(disthedimensionofX )
      for i=1...d  do.
       pickauniformlydistributednumberfrominterval[0,1]as ri
        If ri < CRori=j    then .
          updateXnewi withEq.(8).
        else
         Xnewi = Xi.
        endif
     endfori
    if XnewbetterthanX  then
       X=Xnew
      if XnewbetterthanXbest  then
         Xbest=Xnew
      endif
    endif
  endforn
endwhile
outputthebestsolution
```

III. A Hybrid Algorithm Based on Firefly Algorithm and Differential Evolution

The main bulk of research on the FA algorithm has been demonstrated that, in FA algorithm, each firefly moves to the brighter one and when it does not find any brighter firefly, it performs random walk. The random walk is a simple and weak operator that has been performed in FA. Then, this can be changed, and instead, one can use another strong and better operator so as to make the variation in the desired firefly. To circumvent this deficiency, the hybrid algorithm of FA and DE, hence forth, is called (HFADE) has been proposed. The DE algorithm performs the mutation and crossover on the one firefly which couldnt find a brighter firefly. When the supposed firefly couldnt find a brighter one around itself, then, it might be assumed that the supposed firefly is the local best. So, the DE Crossover and mutation operators apply variation to that local best which could help in find another better place around the firefly under question, and thus, avoiding the trap in local solutions. The general steps of (HFADE) algorithm are as follows: First, The initial population ought to be created, and then, each firefly should be allocated the random position and the cost (light intensity) for that position should also be computed. The next step is the process of firefly algorithm. In this step, based on the value of cost (light intensity) in each firefly, if the preconditions of moving to the another firefly is not satisfied, then, it will be used to perform the process of updating in firefly algorithm by Eq. (6). Otherwise, we go to the next step which performs the process of the DE algorithm. In DE algorithm phase, the mutation and crossover operators are applied on those fireflies which couldnt find their brighter counterparts and the conditions didnt apply to them. The new firefly which has been produced by the DE is compared with the previous one. If the cost (light-intensity) for the newly-produced firefly is better than the previous one, then, it will be swapped with the previous one, and therefore, the new firefly can occupy a position and if the new firefly is better than the global best, then, the global best will also be swapped with the new firefly. Finally, in the last step, if the termination criterion is satisfied, then, the global best firefly should be considered the output. Otherwise, the next iteration will be started from firefly algorithm again. Figure 1 shows the simple flowchart for the proposed algorithm (HFADE). As can be seen in this figure, the (HFADE) is consisted of two main phases, and in each phase, it runs in parallel forms. The proposed hybrid (HFADE) algorithm is as follows:

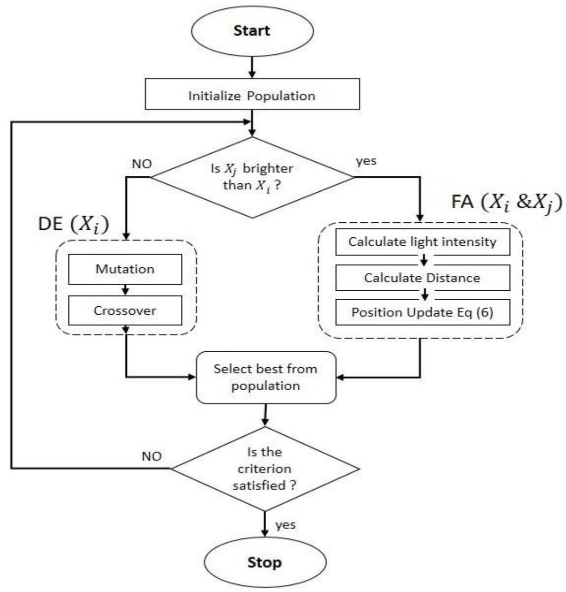


Fig. 1. Flowchart of HFADE algorithm

A. HFADE algorithm

```
HFADEalgorithm:
Input: objectivefunctionf,constraintsandproblemdimension(d)
\\Initialization
Initialparametersn(populationsize), γ , β0, α,CRandF
LetpopulationbethesetofFirefly1,2,...,n
for eachoffirefly do
  Assignrandomrealnumberbetween[L,U]tothefireflyposition
  Calculatefitness(cost)forassignedposition
endfor
\\Mainiterations
while (thestoppingcriterionisnotmet ) do
  for eachoffireflyi(X_i) do
  for eachoffireflyj(X_i) do
  if I(X_i)< I(X_j) then
      CalculatedistanceX_i andX_j byEq.(5)
      Calculate β byEq.(4)
      CreateXnewbyEq.(6)
      if XnewbetterthanX_i then
        X_i = Xnew
      endif
  else
      selectthreefireflya,bandcfrompopulationrandomly
       selectrandomindexqfromq ∈ 1,...,d(disthedimensionofX )
       for k=1...d do,
        pickauniformlydistributednumberfrominterval[01]as r_k
         If r_k < CRork=q then .
          updateXnew_k withEq.(8).
        else
         Xnew_k = X_i^k.
        endif
      endfork
     if Xnewbetterthan X_i then
      X_i = Xnew
      if XnewbetterthanGbest then
         Gbest=Xnew
      endif
     endif
  endif
  endforj
  endfori
  decreasethemutationcoefficient( α ∗ αdampα dampisrealvaluebetween[01])
end while
\\thefinalstage
outputtheminimumvaluefoundGbest
```

B. Complexity and Convergence analysis of HFADE

1) Complexity analysis

HFADE algorithm is consists of 2 main parts and these parts are executed in parallel form in each cycle which are showed at the flow chart Fig. 1. In each part process is performed on agent of population with size of n and agent position is d dimensional vectors. The main operator for each part effects on time complexity. The sections that alter time complexity are: DE Crossover and Mutation, FA position update equation. We can explain complexity analysis of HFADE in worse case and prove the fastest execution of these two algorithms combination like this: As the HFADE algorithms are executed in parallel form, then in each cycle only one of the algorithms is executed. The time complexity for FA is O(nd) and for DE is also O(nd), therefore the HFADE algorithm is run in O(nd) complexity because of the parallel form of execution in FA and DE algorithms.

2) Convergence analysis

For analyzing convergenc of the metaheursitc algorithm, Markov chain Monte Carlo method is the one of the preferrable methods for this task [17]. Most metaheuristic algorithms can be sighted in the framework of Markov chain from statically viewpoint. Now if look at the proposed hybrid method closely using the framework of Markov chain Monte

Carlo, each firefly in HFADE essentially forms a Markov chain and the appropriate better solutions which created in each phase, replace with previous one. Convergence analyzing based on the Markov chain for algorithm HFADE is performed as follows:

Definition 1. Assume that the best firefly is shown by X^* $:= \{x^* \in X : f(x^*) = min(f(x) \mid x \in X)\}$ where X is probable solution and f is fitness function. The number of best fireflies in firefly population is shown by $\lambda(N) :| N \cap O^* |$.

Definition 2. Algorithm convergence with probability 1 to the best if this condition is true :

$\lim_{g \to \infty} P\{\omega(N(g)) \geq 1 \mid N(0) = N_0\} = 1$, where g indicate generation number and N_0 is random initial population.

Theorem 1. HFADE algorithm converges to its globally best solution with probability 1. **Proof:** Let $P_0(g) = P\{\omega(N(g)) = 0\}$ then the probability due to the Bayesian conditional probability of $P_0(g + 1)$ is

$P_0(g{+}1) = P\{\omega(N(g{+}1)) = 0\} \Rightarrow P\{\omega(N(g{+}1)) = 0 \mid \omega(N(g))$ 6$= 0\}{+}P\{\omega(N(g{+}1)) = 0 \mid \omega(N(g)) = 0\}$

Since the best solution replace with previous one in memory, this expression $P\{\omega(N(g + 1)) = 0 \mid \omega(N(g))$ 6$= 0\}$ is true.

Hence, $P_0(g + 1) = P\{\omega(N(g + 1)) = 0 \mid \omega(N(g)) = 0\} \times P\{\omega(N(g)) = 0\}$. $P\{\omega(N(g + 1)) = 1 \mid \omega(N(g)) = 0\} > 0$ is true because of the HFADE algorithm by two main phases FA and DE store the best solution.

Make $\Gamma = minP\{\omega(N(g + 1)) = 1 \mid \omega(N(g)) = 0\}_{min}, g = 0,1,2,...$

Then

$P\{\omega(N(g + 1)) = 0 \mid \omega(N(g)) = 0\}$
$= 1 - P\{\omega(N(g + 1))$ 6$= 0 \mid \omega(N(g)) = 0\}$
$= 1 - P\{\omega(N(g + 1)) \geq 1 \mid \omega(N(g)) = 0\}$
$\leq 1 - P\{\omega(N(g + 1)) = 1 \mid \omega(N(g)) = 0\} \leq 1 - \Gamma < 1$

Therefore,

$0 \leq P_0(g + 1) = P\{\omega(N(g + 1)) = 0\} \leq (1 - \Gamma) \times P\{\omega(N(g)) = 0\} = (1 - \Gamma) \times P_0(g)$. such that, $0 \leq P_0(g + 1) \leq (1 - \Gamma) \times P_0(g)$.

Hence,

$0 \leq P_0(g + 1) \leq (1 - \Gamma) \times (1 - \Gamma) \times P_0(g - 1) \leq ... \leq (1 - \Gamma)^{g+1} \times P_0(0)$.

Given that $\lim_{g \to \infty} (1 - \Gamma)^{g+1} = 0$ and $0 \leq P_0(0) \leq 1$.

Hence $0 \leq g\lim\to\infty\ P0(g) \leq g\lim\to\infty\ (1 - \Gamma)g \times P0(0) = \lim P0(g) = 0\ g\to\infty$
0,

Then $\lim P\{\omega(N(g)) \geq 1 \mid \omega(N(0)) = N_0\}$
$g\to\infty$

$1 - \lim_{g \to \infty} P\{\omega(N(g)) = 0 \mid \omega(N(0)) = N_0\}\ 1 - g\lim\to\infty$
$P0(0) = 1$.

Therefore, when $g \to \infty, P\{\omega(N(g)) \geq 1\} \to 1$. HFADE algorithm could reach to best solution and assurance convergence with probability 1. □

C. Parameter adjustments and boundary control

Parameter adjustment is a non-negligible task which is required to be performed properly in order to get a better result in solving various problems. Besides, the parameter adjustment also is necessary for controlling the boundary whenever the algorithm finds a new solution [18]. The (HFADE) needs boundary control for a Firefly Xi, because its position is required to be in the searching space, which is a boundary between [L U], (L is the lower bound and U is the upper bound of the searching space). The method that controls the boundary is as follows:

$$p = Max(X,L), q = Min(p,U) \qquad (9)$$

Where Min and Max are the functions that select the minimum and maximum among the input pairs, X is the input firefly position and q is the output which have been controlled in the boundary range [L U]. As it was alluded to previously, The DE algorithm is a simple algorithm and enjoys two primary parameters, F and Crossover rate (CR), which is required to be adjusted properly and FA has three main parameters, Light Absorption Coefficient (gamma), Attraction Coefficient Base Value (beta0), and Mutation Coefficient (alpha). So, the combination of two algorithms of FA and DE also enjoys these parameters.

TABLE I. UNIMODAL TEST FUNCTIONS (D: DIMENSIONS)

Function	D	Range	Min	Formulation
F1(Beale)	2	[-4.5,4.5]	0	$- x_1 + x_1x_2)^2 + (2.25 - x_1 + x_1x_2^2)^2 + x_1x_2^3)^2$ $(x_1)\cos(x_2)\,exp(-(x_1-\pi)^2 - (x_2-\pi)^2)$
F2(Easom)	2	[-100,100]	-1	
F3(Matyas)	2	[-10,10]	0	$f(x) = 0.26\left(x_1^2 + x_2^2\right) - 0.48x_1x_2$
F4(Colville)	4	[-10,10]	0	
F5(Zakharov)	10	[-5,10]	0	
F6(Schwefel 2.22)	30	[-10,10]	0	

$$f(x) = 100\left(x_1^2 - x_2\right)^2 + (x_1 - 1)^2 + (x_3 - 1)^2 + 90\left(x_3^2 - x_4\right)^2 + 10.1(x_2 - 1)^2 + (x_4 - 1)^2 + 19.8\,(x_2 - 1)\,(x_4 - 1)$$

$$f(x) = \sum_{i=1}^{D} x_i^2 + \left(\sum_{i=1}^{D} 0.5ix_i\right)^2 + \left(\sum_{i=1}^{D} 0.5ix_i\right)^4$$

$$f(x) = \sum_{i=1}^{D} |x_i| + \prod_{i=1}^{D} |x_i|$$

F7(Schewefel 1.2)	30	[-100,100]	0	$f(x) = \sum_{i=1}^{D} \left(\sum_{j=1}^{i} x_j\right)^2$
				$f(x) = (x_1 - 1)^2 + \sum_{i=2}^{D} i\left(2x_i^2 - x_{i-1}\right)^2$
				$f(x) = \sum_{i=1}^{D} (x_i + 0 \cdot 5)^2$
				$f(x) = \sum_{i=1}^{D} x_i^2$
				$f(x) = \sum_{i=1}^{D} ix_i^2$
				$f(x) = \sum_{i=1}^{D} ix_i^4 + Rand$
F8(Dixon-price)	30	[-10,10]	0	
F9(Step)	30	[-5.12,5.12]	0	
F10(Sphere)	30	[-100,100]	0	
F11(SumSquares)	30	[-10,10]	0	
F12(Quartic)	30	[-1.28,1.28]	0	

IV. Benchmark Test Functions

In this paper, the proposed algorithm has been evaluated with a set of benchmark functions which are a subgroup of unimodal and multimodal functions. These functions have various dimensions such as 2, 4, 10 and 30. Tables 2 highlights a multimodal test functions and Table 1 shows unimdal test functions. Multimodal test functions have many local minimums, and therefore, they are hard to be solved simply because of the trapping in local solutions. The (HFADE) has been evaluated by these functions and search the global minimum for them. In Table 3, the results for algorithms GA [19], DE , PSO, BA [20], PBA [21] and FA that compared with HFADE. Conditions for experiment and paramter settings for these algorithms is explained in reference [21]. The parameter settings for HFADE are as follows: n=20 (populationsize), γ=2 , β_0=2, α=0.2, CR=0.2 and $F \in [0.2\ 0.8]$. The experiment has been performed on the computer with following features: CPU 2.1 GHZ, Ram 8 GB and Matlab 2013 running on computer with windows 10. The NFE= 500,000 (number of function evalution) was set as Stopping criteria and the values minimum than 1E-12, presented as 0 same as other methods. The mean value and Std Dev (standard deviation) have been calculated from 30 independent runs. In Table 3, the HFADE found the minimum results for most of the functions with best standard deviations. It only did not reach the minimum average value in functions Quartic (F12), Dixon-price (F8), Michalewicz 10 (F25) and schewefel 1.2 (F7). The results of Friedman non-parameteric test [22] are also presented in this table and HFADE could rank the best with value 3.15. The low p-value indicates that the results are remarkably different with each other and figure 3 depicts the results for this test with a bar diagram. For analyzing the procedure of convergence in (HFADE), figure 2 has been presented. This figure shows the Convergence diagram for functions F19, F25, F18 and F20 in algorithms FA, DE and (HFADE). As it stands, HFADE has reached the desired minimum with minimum number of iteration and faster against the other algorithms FA.

TABLE II. Multimodal Test Functions (D: Dimensions)

Function	D	Range	Min	Formulation
F13(Schaffer)	2	[-100,100]	0	$f(x) = 0.5 + \frac{\sin^2\left(\sqrt{x_1^2+x_2^2}\right)-0.5}{\left(1+0.001\left(x_1^2+x_2^2\right)\right)^2}$
F14(6 H Camel)	2	[-5,5]	-1.03163	$f(x) = 4x_1^2 - 2.1x_1^4 + \frac{1}{3}x_1^6 + x_1x_2 - 4x_2^2 + 4x_2^4$
F15(Bohachevsky2)	2	[-100,100]	0	$f(x) = x_1^2 + 2x_2^2 - 0.3\cos(3\pi x_1)(4\pi x_2) + 0.3$
F16(Bohachevsky3)	2	[-100,100]	0	$f(x) = x_1^2 + 2x_2^2 - 0.3\cos(3\pi x_1 + 4\pi x_2) + 0.3$

F17(Shubert)	2	[-10,10]	-186.73	$f(x) = \left(\sum_{i=1}^{5} i\cos((i+1)x_1 + i)\right)\left(\sum_{i=1}^{5} i\cos((i+1)x_2 + i)\right)$
F18(Rosenbrock)	30	[-30,30]	0	$f(x) = \sum_{i=1}^{D-1} 100\left(x_{i+1} - x_i^2\right)^2 + (x_i - 1)^2$
F19(Griewank)	30	[-600,600]	0	$f(x) = \frac{1}{4000}\left(\sum_{i=1}^{D}(x_i - 100)^2\right) - \left(\prod_{i=1}^{D}\cos\left(\frac{x_i - 100}{\sqrt{i}}\right)\right) + 1$
F20(Ackley)	30	[-32,32]	0	$f(x) = -20\exp\left(-0.2\sqrt{\frac{1}{n}\sum_{i=1}^{D} x_i^2}\right) - \exp\left(\frac{1}{n}\sum_{i=1}^{D}\cos(2\pi x_i)\right) + 20 + e$
F21(Bohachevsky1)	2	[-100,100]	0	$f(x) = x_1^2 + 2x_2^2 - 0 \cdot 3\cos(3\pi x_1) - 0.4\cos(4\pi x_2) + 0.7$
F22(Booth)	2	[-10,10]	0	$f(x) = (x_1 + 2x_2 - 7)^2 + (2x_1 + x_2 - 5)^2$
F23(Michalewicz2)	2	$[0,\pi]$	-1.8013	$f(x) = -\sum_{i=1}^{D} sin(x_i)\left(\sin\left(ix_i^2/\pi\right)\right)^{20}$
F24(Michalewicz5)	5	$[0,\pi]$	-4.6877	$f(x) = -\sum_{i=1}^{D} sin(x_i)\left(\sin\left(ix_i^2/\pi\right)\right)^{20}$
F25(Michalewicz10)	10	$[0,\pi]$	-9.6602	$f(x) = -\sum_{i=1}^{D} sin(x_i)\left(\sin\left(ix_i^2/\pi\right)\right)^{20}$
F26(Rastrigin)	30	[-5.12,5.12]	0	$f(x) = \sum_{i=1}^{D}\left(x_i^2 - 10\cos(2\pi x_i) + 10\right)$

DE. Also, the test of normality of Kolmogorov-Smirnova and Shapiro-Wilk [22] has been performed for the three functions of F7, F12 and F25 which are hard to be solved, and here, standard deviation is not zero for them. Table 4 presents the results for this test and the p-value, df (degree of freedom), and the statistics for this test are also presented. Accordingly, the p-value which is higher than the significant =0.05 is considered a normal distribution and the lower than that value is supposed to be an abnormal distribution. Based on the p-value and the test of normality of Kolmogorov-Smirnova, the function of F7 result is normal and other functions have the abnormal distribution. Fig.4 shows the normal and abnormal distributions, the histogram, QQ-plot and Box-plot for the two functions, F7 and F12. F7 is a normal distribution and F12 is considered abnormal. As can be inferred, in normal distributions, the results are in one diagonal line for QQ-plot while in abnormal distributions, this fact does not hold true

TABLE III. HFADE COMPARISON WITH GA, DE, PSO, BA, PBA AND FA (UNIMODAL FUNCTION SET), BOLD VALUES REPRESENT THE BEST

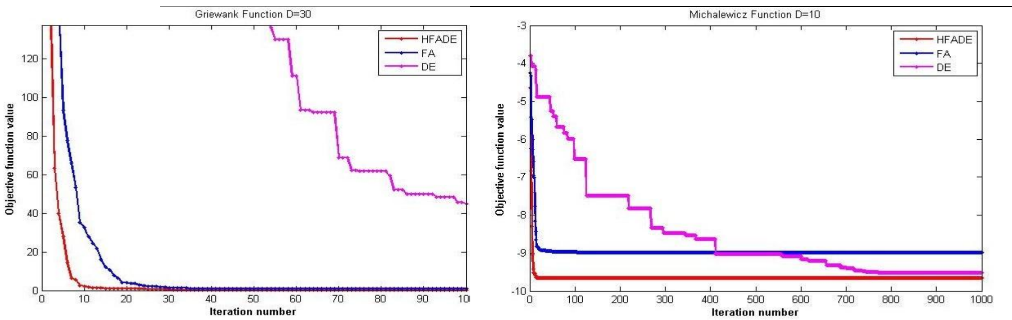
Function	Criteria	GA	DE	PSO	BA	PBA	FA	HFADE
(F1)	Mean	**0**	**0**	**0**	1.88E-05	**0**	**0**	**0**
	StdDev	**0**	**0**	**0**	1.94E-05	**0**	**0**	**0**
(F2)	Mean	**-1**	**-1**	**-1**	-0.99994	**-1**	**-1**	**-1**
	StdDev	**0**	**0**	**0**	4.50E-05	**0**	**0**	**0**
(F3)	Mean	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	StdDev	**0**	**0**	**0**	**0**	**0**	**0**	**0**
(F4)	Mean	0.01494	0.04091	**0**	1.11760	**0**	**0**	**0**

	StdDev	0.00736	0.08198	**0**	0.46623	**0**	**0**	**0**
(F5)	Mean	0.01336	**0**	**0**	**0**	**0**	**0**	**0**
	StdDev	0.00453	**0**	**0**	**0**	**0**	**0**	**0**
(F6)	Mean	11.0214	**0**	**0**	**0**	7.59E-10	2.73028E-10	**0**
	StdDev	1.38686	**0**	**0**	**0**	7.10E-10	1.1535E-11	**0**
(F7)	Mean	7.40E+03	**0**	**0**	**0**	**0**	147.401395	8.514535
	StdDev	1.14E+03	**0**	**0**	**0**	**0**	448.571186	8.768288147
(F8)	Mean	1.22E+03	0.66667	0.66667	0.66667	0.66667	0.66667	0.66667
	StdDev	2.66E+02	E-9	E-8	1.16E-09	5.65E-10	0	0
(F9)	Mean	1.17E+03	**0**	**0**	5.12370	**0**	**0**	**0**
	StdDev	76.56145	**0**	**0**	0.39209	**0**	**0**	**0**
(F10)	Mean	1.11E+03	**0**	**0**	**0**	**0**	**0**	**0**
	StdDev	74.21447	**0**	**0**	**0**	**0**	**0**	**0**
(F11)	Mean	1.48E+02	**0**	**0**	**0**	**0**	**0**	**0**
	StdDev	12.40929	**0**	**0**	**0**	**0**	**0**	**0**
(F12)	Mean	0.18070	0.00136	0.00116	**1.72E-06**	0.00678	3.66E-03	9.70E-04
	StdDev	0.02712	0.00042	0.00028	**1.85E-06**	0.00133	0.001401347	0.00125
(F13)	Mean	0.00424	**0**	**0**	**0**	**0**	**0**	**0**
	StdDev	0.00476	**0**	**0**	**0**	**0**	**0**	**0**
(F14)	Mean	**-1.03163**	**-1.03163**	**-1.03163**	**-1.03163**	**-1.03163**	**-1.03163**	**-1.03163**
	StdDev	**0**	**0**	**0**	**0**	**0**	**0**	**0**
(F15)	Mean	0.06829	**0**	**0**	**0**	**0**	**0**	**0**
	StdDev	0.07822	**0**	**0**	**0**	**0**	**0**	**0**
(F16)	Mean	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	StdDev	**0**	**0**	**0**	**0**	**0**	**0**	**0**
(F17)	Mean	**-186.73**	**-186.73**	**-186.73**	**-186.73**	**-186.73**	**-186.73**	**-186.73**
	StdDev	**0**	**0**	**0**	**0**	**0**	**0**	**0**
(F18)	Mean	1.96E+05	18.20394	15.088617	28.834	4.2831	2.02E+01	1.04E-07
	StdDev	3.85E+04	5.03619	24.170196	0.10597	5.7877	1.147947126	2.95E-07
(F19)	Mean	10.63346	0.00148	0.01739	**0**	0.00468	**0**	**0**
	StdDev	1.16146	0.00296	0.02081	**0**	0.00672	**0**	**0**
(F20)	Mean	14.67178	**0**	0.16462	**0**	3.12E-08	6.56E-10	**0**
	StdDev	0.17814	**0**	0.49387	**0**	3.98E-08	1.24159E-09	**0**
(F21)	Mean	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	StdDev	**0**	**0**	**0**	**0**	**0**	**0**	**0**
(F22)	Mean	**0**	**0**	**0**	0.00053	**0**	**0**	**0**
	StdDev	**0**	**0**	**0**	0.00074	**0**	**0**	**0**
(F23)	Mean	**-1.8013**	**-1.8013**	-1.57287	**-1.8013**	**-1.8013**	**-1.8013**	**-1.8013**
	StdDev	**0**	**0**	0.11986	**0**	**0**	**0**	**0**
(F24)	Mean	-4.64483	-4.68348	-2.4908	**-4.6877**	**-4.6877**	-4.60E+00	**-4.6877**

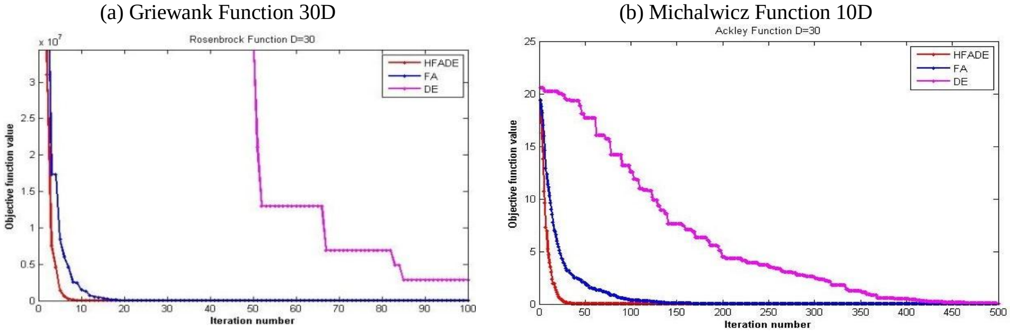
	StdDev	0.09785	0.01253	0.25695	**0**	**0**	0.092696359	**0**
(F25)	Mean	-9.49683	-9.59115	-4.0071	**-9.6602**	**-9.6602**	-9.29521729	-9.653525
	StdDev	0.14112	0.06421	0.50263	**0**	**0**	0.282019302	0.014947
(F26)	Mean	52.92259	11.71673	43.97714	**0**	**0**	47.88406904	**0**
	StdDev	4.56486	2.53817	11.72868	**0**	**0**	16.13200446	**0**
Friedman Test	Rank	5.65	3.65	4.08	3.85	3.56	4.06	3.15
	p-value	3.45E-07						
	Statistic	40.609						

TABLE IV. TEST OF NORMALITY KOLMOGOROV-SMIRNOVA AND SHAPIRO-WILK FOR FUNCTIONS F7,F25 AND F12

	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistic	df	p-value	Statistic	df	p-value
F7	0.1719999	20	0.125	0.858999	20	8.0002E-3
F25	0.4219999	20	0.000	0.4839999	20	0.000
F12	0.5270000	20	0.000	0.3579999	20	0.000



(a) Griewank Function 30D (b) Michalwicz Function 10D



(c) Rosenbrock Function 30D (d) Acley Function 30D

Fig. 2. Convergence diagram for functions F19, F25, F18 and F20 in algorithms FA, DE and HFADE

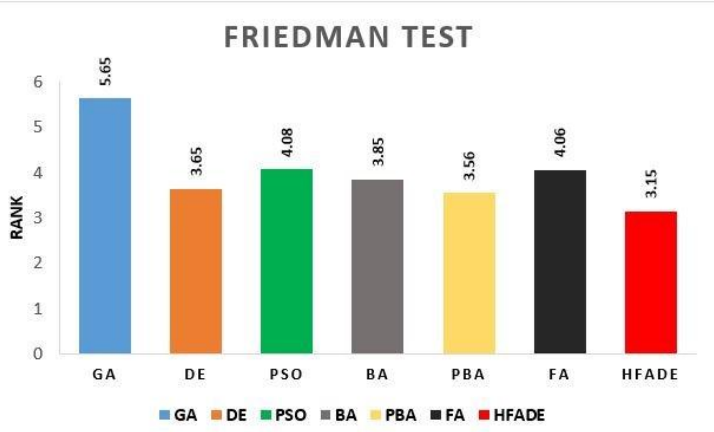


Fig. 3. Bar diagram for non-parametric Friedman test results for Functions F1-F26

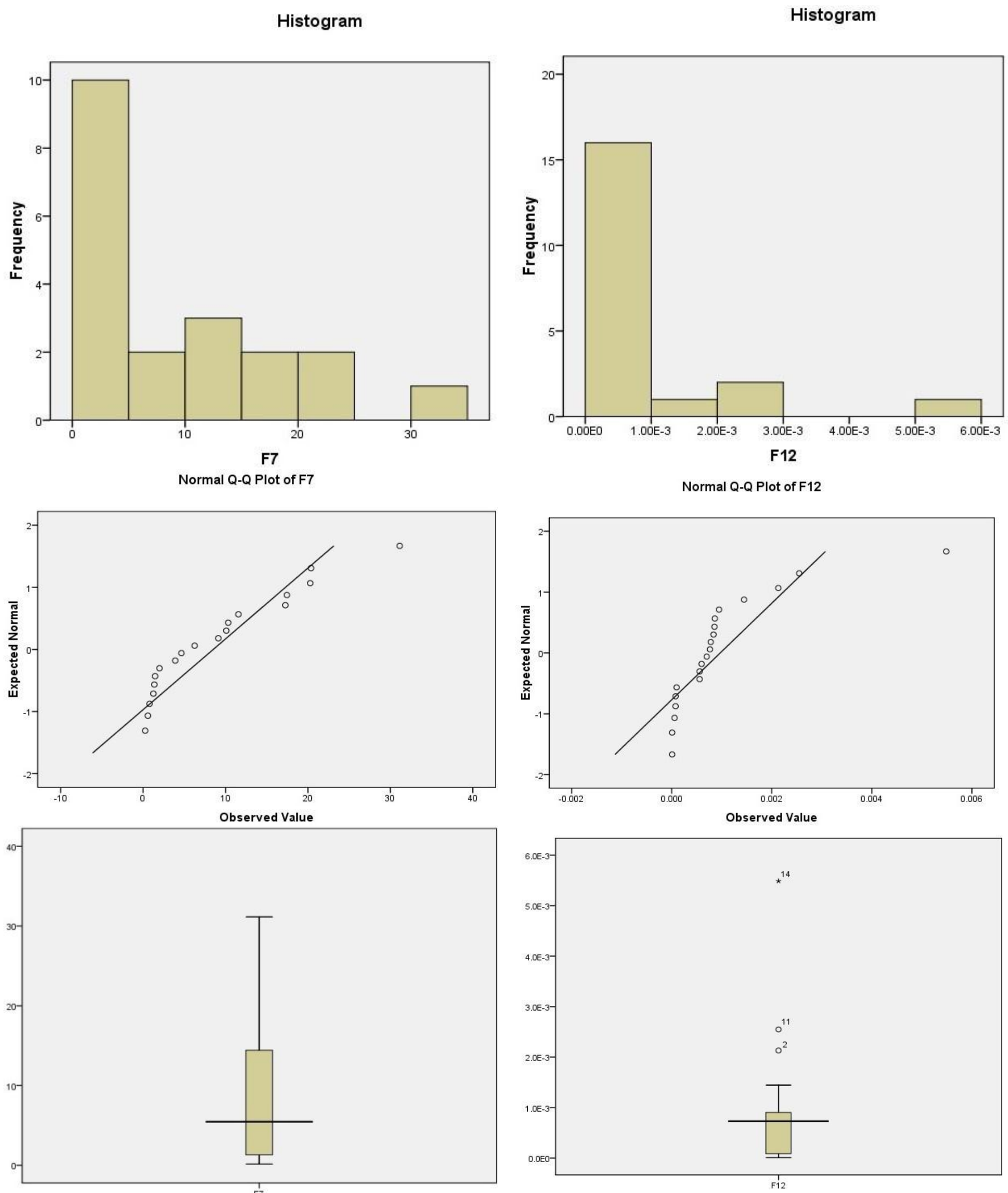


Fig. 4. From top to down respectively: Histogram, Q-Q Graphic and Box plot for functions F7 and F12 results on HFADE algorithm. Left plots are normal for F7 and the Right are abnormal for F12

V. Conclusion

The FA is, arguably, one of the most efficient nature-inspired metaheuristic algorithms, which has outperformed most of the algorithms in solving the various optimizing numerical problems. Furthermore, one of the practical metaheuristic algorithms which have been used most widely in the optimization is the DE. The DE algorithm is a simple and practical algorithm which is more amenable to combination with others. In the current study, the FA and DE algorithms are combined in order to design a new hybrid method for seeking the global solution. The proposed hybrid algorithm begins to search from the FA algorithm if the precondition for entering the FA algorithm is not satisfied the process is passed to the DE which makes the alteration with crossover and mutation operators on the agent of population. The experiment based on benchmark functions and non-parametric ranking shows that the proposed hybrid is more dominant and competent than other famous algorithms. Moreover, based on the results of the test of normality and convergence, this proposed hybrid algorithm mostly has abnormal distributions for results and converges to the optimum solutions in minimum number of iterations.

References

[1] C. Grosan, A. Abraham, Intelligent systems a modern approach, Intelligent Systems Reference Library, Springer Berlin Heidelberg, 2011.

[2] X-S Yang, Introduction to Mathematical Optimization: From Linear Programming to Metaheuristics. Cambridge International Science Publishing, 2008.

[3] P. Hansen, N. Mladenovic, J. Brimberg, J. Moreno-Prez, Variableneighbor- hood search.In:HandbookofMetaheuristics.Springer US, pp. 61-86, 2010.

[4] B. Doˇgan, T. Olmez, A new metaheuristic for numerical function optimization: Vortex search algo-¨ rithm, Information Sciences, pp. 125–145, 2015.

[5] S. Mirjalili, A. Lewis, The Whale Optimization Algorithm, Advances in Engineering Software, pp. 51-67, 2016.

[6] A. Sadollah, A. Bahreininejad, H. Eskandar, M. Hamdi, Mine blast algorithm for optimization of truss structures with discrete variables, Computers & Structures, pp. 49–63, 2012.

[7] H. Eskandar, A. Sadollah, A. Bahreininejad, M. Hamdi, Water cycle algorithm a novel metaheuristic optimization method for solving constrained engineering optimization problems, Computers & Structures, pp. 151–166, 2012.

[8] H. Salimi, Stochastic fractal search: A powerful metaheuristic algorithm, Knowledge-Based Systems, pp. 1–18, 2015.

[9] X.-S. Yang, Nature-Inspired Metaheuristic Algorithms: Second Edition, Luniver Press, 2010.

[10] R. Storn, K. Price, Differential evolution a simple and efficient heuristic for global optimization over continuous spaces, Journal of Global Optimization, pp. 341–359, 1997.

[11] D. Kovaevi, N. Mladenovi, B. Petrovi, P. Miloevi, DE-VNS: Self-adaptive Differential Evolution with crossover neighborhood search for continuous global optimization, Computers & Operations Research, pp. 157–169, 2014.

[12] Mladenovic N,HansenE.Variableneighborhoodsearch.ComputOperRes, pp. 1097-100, 1997.

[13] R.M. Rizk-Allah, Elsayed M. Zaki, Ahmed Ahmed El-Sawy, Hybridizing ant colony optimization with firefly algorithm for unconstrained optimization problems, Applied Mathematics and Computation, pp. 473-483, 2013.

[14] M. Dorigo, T. Sttzle, Ant Colony Optimization, MIT Press, London, 2004.

[15] S. Boyd, L. Vandenberghe, Convex Optimization, Cambridge University Press, 2004.

[16] J. Kennedy, R. Eberhart, Particle swarm optimization. In: Proceedings of the IEEE international conference on neural networks. Perth, Australia, pp. 1942-1948, 1999.

[17] H. Duan, D. Wang, X. Yu, Markov Chains and Martingale Theory Based Convergence Proof of Ant Colony Algorithm and Its Simulation Platform. in Intelligent Control and Automation,pp. 3057–3061, 2006.

[18] W. Chu, X. Gao, S. Sorooshian, Handling boundary constraints for particle swarm optimization in high-dimensional search space. Information Sciences,pp. 4569-4581, 2011.

[19] D. E. Goldberg, Genetic Algorithms in Search, Optimization and Machine Learning, 1st Edition, Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA, pp. 1989.

[20] D. Pham, A. Ghanbarzadeh, E. Ko, S. Otri, S. Rahim, M. Zaidi, The bees algorithm a novel tool for complex optimisation problems, in: D. Pham, E. Eldukhri, A. Soroka (Eds.), Intelligent Production Machines and Systems, Elsevier Science Ltd, Oxford, pp. 454–459, 2006.

[21] M. Cheng, L. Lien, Hybrid artificial intelligencebased pba for benchmark functions and facility layout design optimization, Journal of Computing in Civil Engineering, pp. 612–624, 2002.

[22] S. Garcia, D. Molina, M. Lozano, F. Herrera, A study on the use of non-parametric tests for analyzing the evolutionary algorithms' behaviour: a case study on the CEC'2005 Special Session on Real Parameter Optimization. Journal of Heuristics, pp. 617–644, 2009.

The Development of the Routing Pattern of the Backbone Data Transmission Network for the Automation of the Krasnoyarsk Railway

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***Abstract*—The paper deals with the data transmission network of the Krasnoyarsk Railway, its structure, the topology of data transmission and the routing protocol, which supports its operation, as well as the specifics of data transmission networking. The combination of the railway automation applications and the data transmission network make up the automation systems, making it possible to improve performance, increase the freight traffic volume, and improve the quality of passenger service. The objective of this paper is to study the existing data transmission network of the Krasnoyarsk Railway and to develop ways of its modernization, in order to improve the reliability of the network and the automated systems that use this network. It was found that the IS-IS and OSPF routing protocols have many differences, primarily due to the fact that the IS-IS protocol does not use IP addresses as paths. On the one hand, it makes it possible to use the IS-IS protocol for the operation in IPv6 networks, whereas OSPF version 2 doesn't provide this opportunity; therefore, OSPF version 3 was developed to solve this problem. However, on the other hand, in case of using IPv4, the routing configuration by means of the IS-IS protocol will imply the need to study a significant volume of information and use unusual methods of routing configuration.**

Keywords—Router; Topology; IS-IS protocol; OSPF protocol

I. Introduction

The importance of the rail road is stipulated by large dimensions of the country, absence of all-year river traffic, and absence of river traffic from West to East. Thus, the rail road fulfills an important function, that of delivering cargoes and passengers all around the country and provides 43.2% of total cargo turnover and approximately 33% of passengers turnover in Russia. At present, branches of JSC "Russian Railways" are processing sufficient volume of information on the jobs completed, as well as compiling necessary jobs time-table to satisfy the demands of the consumers. The compiled jobs time-table is to be coordinated with the head office located in Moscow, and also to be distributed among the branches, directorates, companies, and stations engaged into performing the jobs as per compiled working plans. The united data transfer network is used for information distributing. All automated systems consist of automation application and data transfer network, which is necessary for operation of the system. The data transfer network is the basis of the automated systems, and its failure-free operation is very important for the automation system in general. Failure in the data transfer network operation can make absolutely senseless operation of the automation application in case, if there is no possibility to transfer the information, processed by automation application, on operation of the company servicing the rail road, station or directorate. The data transfer can be sufficiently delayed when transferring large data volumes using voice communication or low speed mobile data transfer network. When functionality of the data transfer network is recovered, the importance of collected information can be already lost. Also, improper operation of the data transfer network can lead to partial loss of the information and consequently one cargo rail car will be reserved for various customers, or the seat in the passenger car will be occupied by two different passengers having in their possession the tickets bought using the Internet-service, because the information on one of them was not delivered to the united data base of JSC "Russian Railways" and the seat was not flagged as occupied one, so a ticket for the seat was sold second time.

Therefore, the data transfer network is an important element of operation of the automated systems used by JSC "Russian Railways", and properly designed or modernized data transfer network plays important role in functioning the company "Russian Railway" in general and its separate branches as well. JSC Russian Railways (JSC RZD) is Russia's largest railway company; it also ranks among the top three major railway corporations in the world. The Krasnoyarsk Railway is a branch of JSC "Russian railways". To ensure the effective work of JSC "Russian railways", various automated systems are used. The number of such systems is about 150 to 200; it is difficult to determine the exact number, as some branches and services apply their own automation systems to improve the performance of subdivisions. In particular, the following systems can be mentioned: ASOUP (Automated Traffic Control System); ETRAN (Electronic Waybill); Express-3; ASKUE (Automated system of commercial power accounting).

The data transmission network of the Krasnoyarsk Railway covers all stations and enterprises serving the railway. Depending on the size of a station, its geographical location and functions, it has a network with various bandwidth, from 2 MB/s, organized using the existing physical lines, up to 1 GB/s, organized with the use of fiber-optic network; a network with a bandwidth of up to 1 GB/s necessarily connects peripheral transport hubs and the regional hub, as well as major stations (Figure 1).

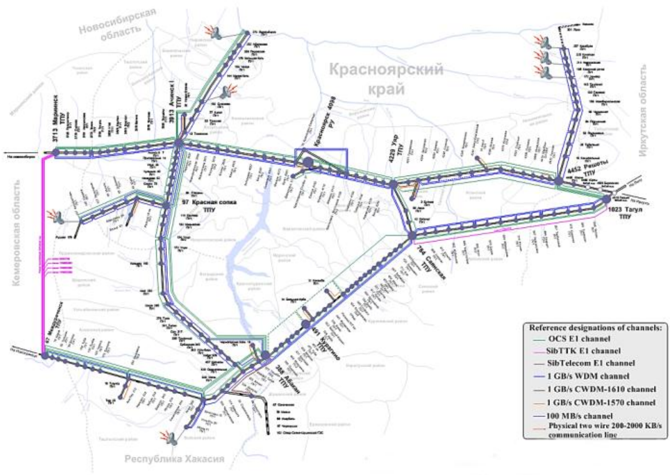


Fig. 1. Topological diagram of the data transmission network of the Krasnoyarsk Railway

II. Methodology

A. The method of data addressing of the Krasnoyarsk Railway

The data transmission network of the Krasnoyarsk Railway uses the OSPF routing protocol. The OSPF protocol makes it possible to segment the network into many areas, but at the same time, all the areas will be merged into a single routing domain, or, in other words, a single autonomous system [1].

All IP address space, available to JSC RZD, is divided between different paths by individual segments. This division makes it possible to order the distribution of information and simplify the configuration of addressing for JSC "RZD" in general and for its individual branches, as well as for different areas of the data transmission network. As each device (printers, terminals, computers) in the network must have a unique IP address in order to be able to communicate with other devices, the network must have an adequate range of IP addresses, from which an IP address for each device can be allocated. The Krasnoyarsk Railway has a set of IP addresses, allocated from the total IP address pool, available to JSC RZD, which is used by all devices for data transmission, both within the Krasnoyarsk Railway and for connection with other roads. Besides, each of the pools is divided into 5 VPNs (Virtual Private Network is the generic name of technologies that provide one or more network connections [logical network] over a different network), which perform different functions, including data transmission network management, maintenance of automated systems Express 3, ETRAN, etc.

Each station is equipped with networks, belonging to all three pools, and at least three types of VPNs: Legacy (data transmission network management), Express (System Express 3), VPN 2 (other). Thus, the number of routes, which should be stored by each router, at each station is approximately equal to

$$1017 \cdot 3 \cdot 3 = 9153 \qquad (1)$$

With allowance for the VPNs, which are necessarily present at all communications centers, we get the number 9153, but it should be remembered that some stations may also be equipped with VPNs required for the servicing of commercial subscribers and organizing video monitoring. These VPNs should also be recorded in the memory of each router, which further loads the routers installed at communications centers, and the resulting number of networks may differ considerably from the calculated minimum. Besides, the number of networks is constantly changing, so the resulting number of networks can vary within 10% [2].

To determine the amount of memory occupied by each entry of the topology table, a routing testbed was used, the diagram of which is presented in Figure 2.

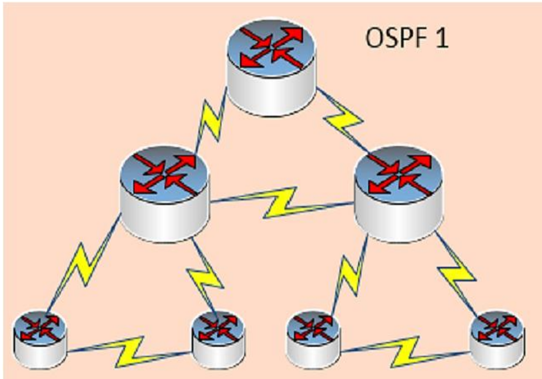


Fig. 2. The diagram of the routing testbed

To calculate the amount of memory occupied by the entries of routes, it is necessary to use the **show IP route summary** command. For various topologies, having different number of subnets, the results of the command execution are shown in Table 1.

TABLE I. THE AMOUNT OF MEMORY OCCUPIED BY ONE SUBNET

Route Source	Networks	Subnets	Overhead	Memory (bytes)	The amount of memory required to store one entry (bytes)
ospf 1	0	1	72	136	136
ospf 1	0	2	144	272	136
ospf 1	0	4	288	544	136
ospf 1	0	6	432	816	136
ospf 1	0	7	504	952	136
ospf 1	0	9	648	1224	136

The table shows that each new subnet occupies 136 bytes in the memory of the router. Thus, to store 9153 records, the following amount of memory is required:

$$9153 \cdot 136 = 1244808 \text{ byte} = 1.18 \text{ Mbytes} \qquad (2)$$

Besides, a relatively equal amount of memory is occupied by the topology tables on each device; thus, reducing the size of topology tables will also result in the reduction of the amount of occupied memory, which will have a beneficial impact on the performance of installed equipment. The reduction of the amount of memory, occupied by subnets, will provide an opportunity to continue using the installed routers in case of network expansion, which will make it possible to reduce the cost of maintaining network health [3].

III. RESULTS

A. Core OSPF routing protocol

The OSPF routing protocol ensures the transmission of IP packets based on the IP address of the recipient of the packet; the IP addresses of the recipients of the packet are defined in the IP packet header. In the process of sending an IP packet, its content is not changed. That is, no encapsulation into other packets takes place [4]. To exchange information about the communication channels which are known to the router, small packets called link state advertisements (LSA) are used [5].

B. Address table and OSPF areas

The Krasnoyarsk Railway uses the OSPF routing protocol for data transmission. That is, the network covering the entire railway is divided into separate areas, but at the same time the network as a whole is a single routing domain. In addition to individual areas, covering specific parts of the railroad, there is also an area 0, which includes all area border routers and ensures distribution of routing information between other areas. The division of the entire data transmission network into different areas is shown in Figure 3.

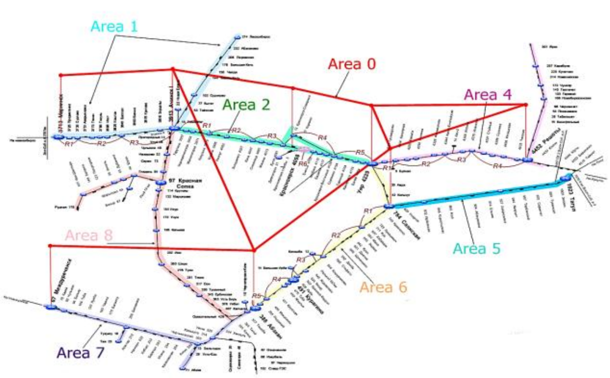


Fig. 3. OSPF areas of the Krasnoyarsk railway

The entire data transmission network is divided into 8 areas (area 3 is absent, as it was merged with area 4). The division is based on the geographical distribution of the data transmission network. Area 0, unlike other areas, topographically covers the entire data transmission network and performs the functions of communication between an all the other areas, ensuring fast data transfer between areas. Redistribution of routing information should be used if there are different routing protocols in the data transmission network [6]. Even if different routing protocols are running on one router, it does not mean that the router will automatically start transferring information from one protocol to another. The reason for that is that different routing protocols use different metrics, which makes it impossible to automatically transfer information from one protocol to another. The redistribution of routing information can be either carried out in one direction, or be bilateral. Bilateral distribution is not always possible, for example, in case of using outdated equipment in a certain network segment, which does not support the core routing protocol. In this case, the process of the redistribution of routing information to this segment of the network can be configured, while inverted distribution can lead to the overload of the equipment. Besides, the bilateral distribution of routing information can lead to the destruction of the metric domain and the formation of routing loops. Various routing protocols use different algorithms for calculating metrics [7]. However, regardless of the specific algorithm for calculating metrics, metrics of all routing protocols have one common property – they increase linearly with the increase of the number of transitions on the path from the recipient network.

Formally, the cumulative nature of the metrics can be described by the following expression (3).

$$\forall d \text{ and } d', \text{where } d' > d, M(d') > M(d) \qquad (3)$$

where d and d` – the number of transitions on the path from the recipient network. M (x) is a function of the metric.

Given this common property of the metrics of routing protocols, it is possible to define the metric domain of a routing protocol as a part of the data transmission network, in which the metrics of a routing protocol reflect the distance to the recipient network and satisfy the (3). Metrics are calculated in accordance with the algorithm, prescribed by the routing protocol, which is running on routers [8]. In other words, any router within the metric domain of the routing protocol calculates the metrics of routes to the recipient networks within the metric domain in accordance with the algorithm, prescribed by the routing protocol. If a router uses any other algorithm to calculate the metric of a route to the recipient network, then this router is located beyond the metric domain, to which the recipient network belongs.

To enable the mechanism of the redistribution of routing information, the **redistribute** command is used. The general syntax of the command is shown below.

(config-router)#**redistribute** *protocol* [**metric** *metric-value*][**tag** *tag-value*] [**route-map** *map-tag*]

(config-router)# **no redistribute** *protocol* [**metric** *metric-value*][**tag** *tag-value*] [**route-map** *map-tag*]

The parameters of the **redistribute** command are shown in Table 2.

TABLE II. THE PARAMETERS OF THE REDISTRIBUTE COMMAND

Parameter	Description
Protocol	Routing information source
metric *metric-value*	The metric, assigned for redistributed routes
tag *tag-value*	A tag, assigned for using in the route redistribution control
route-map *map-tag*	The name of the route map used for redistribution

Each new routing protocol should have its own number. To order the numbering of OSPF processes, the following rule is applied: the first digit is the number of the OSPF area, the second digit is the number of the segment of the considered area, the third digit is the number of VRF [9]. The routing processes, which are to be configured for area 1, are specified in Table 3. Configuring these routing processes makes it possible to separate both segments of area 1 from the general network and transfer the information to the neighboring segments; accordingly, their addresses will be stored only by the routers installed at peripheral transport hubs, whereas the internal routers will only know the routes to the routers, located in the same segment, and a default route to the routers of peripheral transport hubs.

TABLE III. THE ROUTING PROCESSES OF AREA 1

Areas	The routing process for the Express system	The routing process for the control process	The routing process for other processes
Segment 1	OSPF111	OSPF1188	OSPF112
Segment 2	OSPF121	OSPF1288	OSPF122

The routing processes, which are to be configured at peripheral transport hubs, located at Achinsk and Uyar railway stations, as well as at the regional transport hub, located at Krasnoyarsk railway station, are specified in Table 4.

TABLE IV. THE ROUTING PROCESSES OF AREA 2

Areas	The routing process for the Express system	The routing process for the control process	The routing process for other processes
Segment 1	OSPF211	OSPF2188	OSPF212
Segment 2	OSPF221	OSPF2288	OSPF222

The routing processes, which are to be configured to ensure the correct operation of the mechanism of the redistribution of routing information, are specified in Table 5.

TABLE V. THE ROUTING PROCESSES OF AREA 4

Areas	The routing process for the Express system	The routing process for the control process	The routing process for other processes
Segment 1	OSPF411	OSPF4188	OSPF412
Segment 2	OSPF421	OSPF4288	OSPF422

To ensure the correct operation of the mechanism of the redistribution of routing information at peripheral transport hubs, located at Sayanskaya and Tagul railway stations, it is necessary to configure OSPF routing protocols, the names of which are listed in Table 6.

TABLE VI. THE ROUTING PROCESSES OF AREA 5

Areas	The routing process for the Express system	The routing process for the control process	The routing process for other processes
Segment 1	OSPF511	OSPF5188	OSPF512
Segment 2	OSPF521	OSPF5288	OSPF522

The routing processes, which are to be configured to ensure correct operation of the mechanism of the redistribution and reducing the size of the topology tables of internal routers, are specified in Table 7.

TABLE VII. THE ROUTING PROCESSES OF AREA 6

Areas	The routing process for the Express system	The routing process for the control process	The routing process for other processes
Segment 1	OSPF611	OSPF6188	OSPF612
Segment 2	OSPF621	OSPF6288	OSPF622
Segment 3	OSPF631	OSPF6388	OSPF632

The routing processes, which are to be configured to ensure the correct operation of the mechanism of the redistribution of routing information, are specified in Table 8.

TABLE VIII. THE ROUTING PROCESSES OF AREA 7

Areas	The routing process for the Express system	The routing process for the control process	The routing process for other processes
Segment 1	OSPF711	OSPF7188	OSPF712

The routing processes, which are to be configured at peripheral transport hubs, are specified in Table 9.

TABLE IX. THE ROUTING PROCESSES OF AREA 8

Areas	The routing process for the Express system	The routing process for the control process	The routing process for other processes
Segment 1	OSPF 811	OSPF 8188	OSPF 812
Segment 2	OSPF821	OSPF8288	OSPF822
Segment 3	OSPF831	OSPF8388	OSPF832

An epxample of the configuration of the redistribution of routing information.

To redistribute routing information, it is necessary to configure in the processes, related to the processes of the transfer of information in the backbone area (area 0), the process of the redistribution of information from internal areas into the backbone area. An example of the configuration is shown below.

#configure terminal
(config)#router ospf 1

(config-router)# redistribute ospf 121 metric 10 subnets

The use of this command makes it possible to redistribute information from the internal area (in this case, the area, in which the OSPF 121 protocol operates) into the backbone area, in which the distribution of information is controlled by the OSPF 1 process.

To transfer information from the backbone area into the internal area, it is necessary to use the **default-information originate** command that configures a default route for the OSPF Protocol [10]. The general syntax of the command is shown below.

(config-router)# **default-information originate [always] [metric** *metric-value***]**
[metric-type *type-value***]** [**route-map** *map-name*]

(config-router)# **no default-information originate**

The description of the parameters of the **default-information originate** command is provided in Table 10 below.

TABLE X. THE PARAMETERS OF THE DEFAULT-INFORMATION ORIGINATE COMMAND

Parameter	Description
Always	Always propagate a default route, regardless of the algorithms of automatic assignment of default routes in the OSPF protocol
metric *metric-value*	Route metric. The default value is 10
metric-type *type-value*	The type of the external route: 1 – 1 the type of the external route 2 – 2 the type of the external route The default value is 2
route-map *map-name*	An instruction for the routing process to propagate a default route, in case if the **route-map** condition is met

To configure the default route for the internal area serviced by the 121 OSPF protocol, it is necessary to use the following set of commands:

#configure terminal
(config)#router ospf 1
(config-router)#default-information originate always

This is the way to configure the default route and, accordingly, the transfer of information from the OSPF protocol, used in the internal area, to the OSPF 1 protocol, related to the backbone area [11]. The redistribution is required to ensure that various routing processes, for example, OSPF 1 and OSPF 121, running on one router, can exchange information, in particular, so that the OSPF 1 routing process gets information on the individual networks available to the OSPF 121 routing process. Figure 4 illustrates the process of transferring information from one area into another, or from one routing process to another.

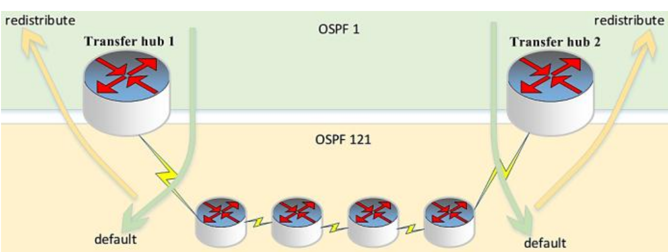


Fig. 4. The redistribution of routing information between different routing processes running on the same router

Conclusions of efficiency of the route information redistribution mechanism operation.

Redistribution of the route information for the data transfer network can allow to arrange up to 15 zones of the data transfer network and, respectively, in average by 15 times reduce volume of information stored in each of its internal routers. This reduction of stored information favorably influences the speed work of the routers installed in the remote nodes of the first and the second type, which as a rule, feature small volume of memory and can be obsolete devices, for which storing and processing large tables of routing and topology can create sufficient load. Despite evident advantages of route information redistribution mechanism, it possesses some drawbacks, limiting its use and requiring high qualification of the specialists, adjusting the mechanism. Also, it is rather complicated to support functionality of the network and to search for the failures source.

IV. CONFIGURING TOTALLY STUB AREAS

A stub area does not receive information about external links, imported into the OSPF routing domain. External links, which arrive into the stub area in the form of Type 5 LSAs, are automatically substituted by the area border router of the area for the default route to the area border router. The area border router has full information on all the external links in the OSPF routing domain. Stub areas can't contain area border routers of autonomous systems [12].

Totally stub area: An area, which receives neither information on external links, nor Type 3 and 4 LSAs, which are the internal links for the given OSPF routing domain. All external and inter-area routes are substituted by the area border router for the default route to the area border router [13]. Totally stub areas can't contain area border routers of autonomous systems. In a totally stub area, all the external and inter-area routes are blocked, that is, the routing table of the routers, located inside a totally stub area, contains only intra-area routes and a default route to the area border router [14]. The comparison of the processes of dissemination of the topology information in a totally stub area and a standard area is shown in Figure 5.

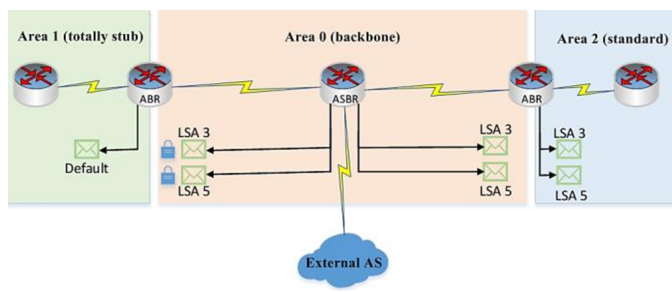


Fig. 5. The dissemination of the topology information in a totally stub area and a standard area

In addition to the rule that totally stub areas can not contain area border routers of autonomous system, a totally stub area should also comply with the following rules.

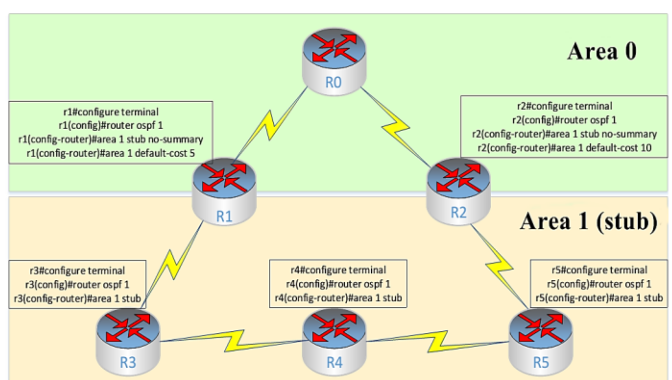


Fig. 6. An example of the configuration of a totally stub area

- An area doesn't contain virtual channels.
- An area is not a backbone one.
- An area has one exit point to the backbone area.

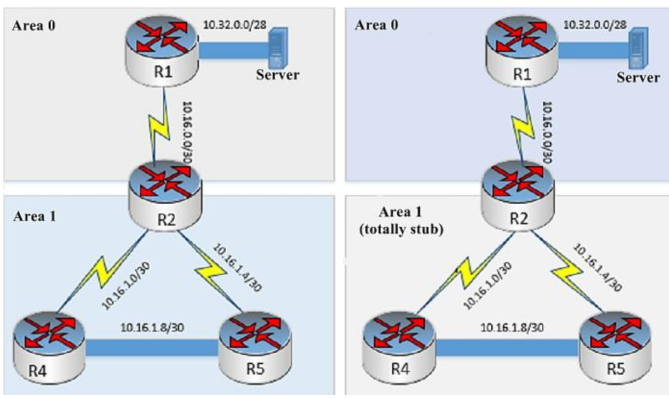
For the purpose of the description of the configuration of a totally stub area, Figure 6 can be used.

To configure a totally stub area, two commands are used, which were described in detail above.

area *area-id* **default-cost** *cost*
area *area-id* **stub** [no-summary]

It should be noted that the keyword **no-summary**, preventing the transfer of the inter-area Type 3 and 4 LSAs into a totally stub area, is added only in case of configuration of area border routers.

In order to confirm the effectiveness of reducing the size of routing tables in case of using totally stub areas, the emulation was carried out using testbeds, the diagrams of which are shown in Figure 7 (a) and 7 (b). Both routing schemes have two routing areas, but one of the schemes has normal areas, while the second one has a totally stub area.



a) *b)*

Fig. 7. Diagrams of the testbeds without a totally stub area a) and with a totally stub area b)

To compare the volume of routing tables, the **show ip route** command was used. The results are shown below; it must be emphasized that the presented routing tables are the routing tables of the R4 router, located in the totally stub area.

Without division into areas:

R4#show ip route
10.0.0.0/8 is variably subnetted, 7 subnets, 3 masks
O 10.0.1.1/32 [110/65] via 10.16.1.1, 00:03:57, Serial0/0
O IA 10.0.0.1/32 [110/129] via 10.16.1.1, 00:02:16, Serial0/0
C 10.16.1.8/30 is directly connected, FastEthernet0/0
O IA 10.16.0.0/30 [110/128] via 10.16.1.1, 00:03:56, Serial0/0
C 10.16.1.0/30 is directly connected, Serial0/0
O 10.16.1.4/30 [110/65] via 10.16.1.10, 00:03:57, FastEthernet0/0
O IA 10.32.0.0/28 [110/129] via 10.16.1.1, 00:02:16, Serial0/0

The OSPF routing protocol is a link state protocol, and it has accurate information on the topology of the data transmission network, on the basis of which a routing table is built [15]. The routing table for the routing process without creation of a totally stub area contains routes for all devices, as prescribed by the protocol operation algorithm. Besides, it doesn't contain a default route.

With the use of a totally stub area:

R4#show ip route
10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
O 10.0.1.1/32 [110/65] via 10.16.1.1, 00:02:09, Serial0/0
C 10.16.1.8/30 is directly connected, FastEthernet0/0
C 10.16.1.0/30 is directly connected, Serial0/0
O 10.16.1.4/30 [110/65] via 10.16.1.10, 00:02:09, FastEthernet0/0
O*IA 0.0.0.0/0 [110/65] via 10.16.1.1, 00:02:09, Serial0/0

In case of using a totally stub area, the routing table only contains the routes to the routers, located within this area, and a default route [16]. Even on such a small testbed, a significant reduction of the size of the routing table was observed; in case of increasing the number of the routers outside the totally stub area, the difference between the topology tables and the amount of occupied memory for routers located in the totally stub areas and those located in the generic domain, without division into areas, will only increase.

In case of the creation of totally stub areas for the entire data transmission network of the Krasnoyarsk Railway, each of the routers will have to store information not on all the 9153 networks, but only on 610 networks on the average. Thus, the average amount of occupied memory is determined by Equation (4).

$$610 \cdot 136 = 82\ 960 \text{ bytes} = 81.016\text{Kbytes} \quad (4)$$

The information on the amount of memory, occupied by an entry of one route, is taken from the table; this amount was calculated by means of testbed emulation with different number of networks. To store the entries of all the routes, 1215.63 Kbytes of memory are required.

The calculations show that using totally stub areas makes it possible to significantly reduce the amount of occupied memory, and also reduce the processor load by reducing the amount of processed information.

Conclusions on the efficiency of using completely dead-end zones.

Use of completely dead-end zones allows to reduce sufficiently the tables of routing and the tables of topology being stored in the access level routers, as well as to divide the whole data transfer network into several segments, existing topology can be divided maximum into 15 segments. This leads to reduction of load on the routers and provides possibility to use existing equipment even when enhancing the data transfer network. Increasing the data transfer network in no way influences the routers of the lower access level, because they are not connected with the routers irrelevant to this completely dead-end zone. Besides the evident advantages, the use of completely dead-end zones brings some disadvantages, for instance – impossibility of flexible change of completely dead-end zones.

V. Using The IS-IS Routing Protocol

Along with the possible ways of changing the OSPF routing protocol, used in the data transmission network of the Krasnoyarsk Railway, the possibility of using other routing protocols, for example, the more advanced IS-IS protocol, should also be considered. The IS-IS routing protocol, as well as the OSPF protocol, is a link state protocol [17]. That is, both protocols are characterized by using the same algorithm for searching the shortest path to other routers in the network, as well as the fast convergence of networks, i.e. the ability to quickly find alternative routes to devices belonging to the network, in case of sudden changes in the network topology [18]. The route metric in the OSPF and IS-IS protocols has some differences. For the IS-IS Protocol, as well as for the OSPF protocol, the metric is a number without dimension, and the route metric is calculated as the sum of the metrics of its constituent channels. However, ,in the IS-IS protocol, it is also possible to set three additional metrics: "delay", showing the length of the delay in the channel, "expense", showing the communication costs, and "error", showing the error rate in the channel [19].

When operating the routing protocol IS-IS, all the routers are divided into 3 levels as follows.

- Level 1 (analogue to in-zone routers in OSPF-protocol) – the routers knowing the routes inside the zone they are relevant to.
- Level 2 (analogues to OSPF-protocol zone 0 routers– the routers storing the information on the routes between the zones.
- Level 1-2 (analogue of the border routers in OSPF-protocol) – the routers knowing the routes between the zones, as well as within the zone they belong to.

The routers of level 1 can transfer information only to the routers of the first level, belonging to the same zone of data transfer network, same as the routers of the second level can exchange information only with the routers of level 2. It is the routers of 1-2 level which are used to install the communication between them; besides, these routers can transfer information to other routers of 1-2 level.

The important difference from OSPF-protocol is in the fact that the routers of 1-2 level are located in some network zone but are not located between the zone 0 and the zone where they transfer information to. The differences are vividly illustrated by the Figure 8 and 9.

The Figure 8 presents connection of the routers relevant to three zones, at that the zones 1 and 2 contain the routers of user's access level routers, the zone 0 contains the router which is the basic one and which is redistributing the information between the zones 1 and 2. The routers R2 and R3 are the border routers and connect the basic zone with the zones 1 and 2; these routers do not belong to any detailed zone.

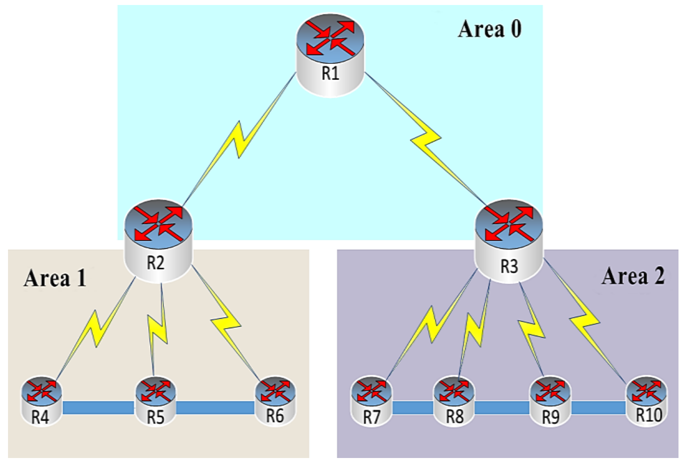


Fig. 8. Connecting multiple routers in the OSPF protocol zones

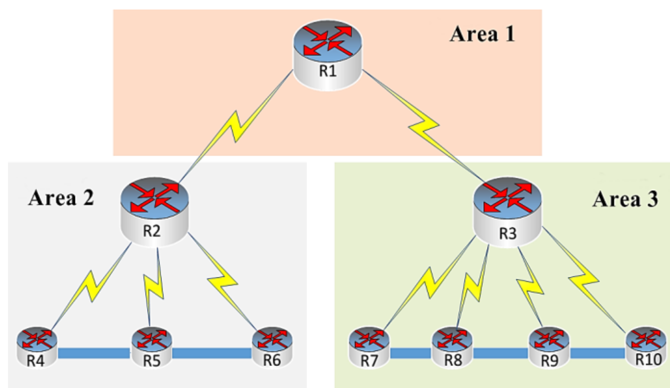


Fig. 9. Connecting routers multiple zones in the protocol IS-IS

Figure 9 presents example of connecting several routers, located in several different zones with using routing protocol IS-IS. The difference with connecting the routers using OSPF-protocol is in the fact that the routers of 1-2 level are located not at the border of two zones, but in some zone. In example given by the figure, the routers R2 and R3 are the routers of 1-2 level. The routers of user's access level, in this case R4-Rr10, are the routers of level 1. The R1 router is the router of level 2. Another difference from OSPF-protocol is the fact that the basic zone does not necessarily have the number 0, it can have any number.

A. The comparison of the OSPF and IS-IS protocols

To obtain information about the operation of the OSPF protocol, a testbed was used, the diagram of which is presented in Figure 10.

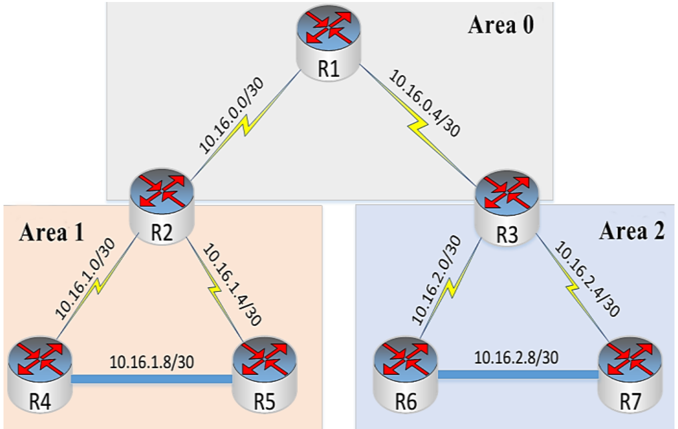


Fig. 10. The model of the data transmission testbed model

To obtain the performance characteristics of the routers, a scheme with 3 areas was used - two standard areas (areas 1 and 2) and a backbone area (area 0). Accordingly, the R1 router is located in the backbone area and ensures the transfer of information from the area border routers R2 and R3 of the standard areas. The R4-R7 routers are user access level routers. For the comparison of the efficiency of the OSPF and IS-IS protocols in terms of occupied memory and CPU resources, required for the procession of routes, of the most interest are routing tables and databases, stored in the memory of area border routers [20].

The routing table for the R3 router is presented below.

R3#show ip route
10.0.0.0/8 is variably subnetted, 10 subnets, 2 masks
C 10.0.2.1/32 is directly connected, Loopback0
O 10.16.2.8/30 [110/65] via 10.16.2.6, 00:00:48, Serial0/2
[110/65] via 10.16.2.2, 00:00:48, Serial0/1
C 10.16.0.8/30 is directly connected, FastEthernet0/0.401
O IA 10.16.1.8/30 [110/193] via 10.16.0.5, 00:00:48, Serial0/0
C 10.16.2.0/30 is directly connected, Serial0/1
O 10.16.0.0/30 [110/128] via 10.16.0.5, 00:00:53, Serial0/0
O IA 10.16.1.0/30 [110/192] via 10.16.0.5, 00:00:50, Serial0/0
C 10.16.2.4/30 is directly connected, Serial0/2
C 10.16.0.4/30 is directly connected, Serial0/0
O IA 10.16.1.4/30 [110/192] via 10.16.0.5, 00:00:50, Serial0/0

It can be seen that the routing table even of such a small testbed, which includes only data transmission devices without target devices, contains 10 networks, stored in the memory of area border routers. As the areas are not stub, each router stores the same routing tables, for example, the routing table, stored in the memory of the user access level router R4, contains the same number of entries; this table is presented below.

R7#show ip route
10.0.0.0/8 is variably subnetted, 10 subnets, 2 masks
C 10.0.2.3/32 is directly connected, Loopback0
C 10.16.2.8/30 is directly connected, FastEthernet0/0.421
O IA 10.16.1.8/30 [110/257] via 10.16.2.5, 00:42:23, Serial0/0
O 10.16.2.0/30 [110/65] via 10.16.2.9, 00:42:23, FastEthernet0/0.421
O IA 10.16.0.0/30 [110/192] via 10.16.2.5, 00:42:23, Serial0/0
O IA 10.16.1.0/30 [110/256] via 10.16.2.5, 00:42:25, Serial0/0
C 10.16.2.4/30 is directly connected, Serial0/0
O IA 10.16.0.4/30 [110/128] via 10.16.2.5, 00:42:25, Serial0/0
O IA 10.16.1.4/30 [110/256] via 10.16.2.5, 00:42:25, Serial0/0

Area border routers store databases, which contain data on the backbone area and the area to which they are connected; therefore, the databases of area border routers have the largest volume and occupy a large amount of memory. The database, stored in the memory of the area border router, is presented below.

r3#show ip ospf database
OSPF Router with ID (10.0.2.1) (Process ID 1)

Router Link States (Area 0)

Link ID ADV Router Age Seq# Checksum Link count
10.0.0.1 10.0.0.1 1823 0x80000005 0x0066FF 4
10.0.1.1 10.0.1.1 250 0x80000005 0x008FB9 2
10.0.2.1 10.0.2.1 1824 0x80000003 0x00122F 2

Summary Net Link States (Area 0)

Link ID ADV Router Age Seq# Checksum
10.16.1.0 10.0.1.1 1017 0x80000003 0x004096
10.16.1.4 10.0.1.1 1017 0x80000003 0x0018BA
10.16.1.8 10.0.1.1 1017 0x80000003 0x00F9D3
10.16.2.0 10.0.2.1 818 0x80000005 0x002AA8
10.16.2.4 10.0.2.1 818 0x80000004 0x0004CB
10.16.2.8 10.0.2.1 818 0x80000002 0x00E9E2

Router Link States (Area 2)

Link ID ADV Router Age Seq# Checksum Link count
10.0.2.1 10.0.2.1 818 0x80000003 0x0062F4 4
10.0.2.2 10.0.2.2 806 0x80000005 0x007D67 3
10.0.2.3 10.0.2.3 794 0x80000005 0x006C6D 3

Net Link States (Area 2)

Link ID ADV Router Age Seq# Checksum
10.16.2.10 10.0.2.3 1049 0x80000003 0x006C7C

Summary Net Link States (Area 2)

Link ID ADV Router Age Seq# Checksum
10.16.0.0 10.0.2.1 821 0x80000002 0x00C8CE
10.16.0.4 10.0.2.1 821 0x80000002 0x001EB5
10.16.1.0 10.0.2.1 821 0x80000002 0x004016
10.16.1.4 10.0.2.1 821 0x80000002 0x00183A
10.16.1.8 10.0.2.1 821 0x80000002 0x00F953

As can be seen, area border routers need to store a large amount of information, related to several areas of the data transmission network, which occupies a large amount of memory.

The database, stored by the user access level router, is presented below.

r4#show ip ospf database

OSPF Router with ID (10.0.2.3) (Process ID 1)
Router Link States (Area 2)

Link ID ADV Router Age Seq# Checksum Link count
10.0.2.1 10.0.2.1 897 0x80000003 0x0062F4 4
10.0.2.2 10.0.2.2 880 0x80000005 0x007D67 3
10.0.2.3 10.0.2.3 867 0x80000005 0x006C6D 3

Net Link States (Area 2)

Link ID ADV Router Age Seq# Checksum
10.16.2.10 10.0.2.3 1122 0x80000003 0x006C7C

Summary Net Link States (Area 2)

Link ID ADV Router Age Seq# Checksum
10.16.0.0 10.0.2.1 897 0x80000002 0x00C8CE
10.16.0.4 10.0.2.1 897 0x80000002 0x001EB5
10.16.1.0 10.0.2.1 897 0x80000002 0x004016
10.16.1.4 10.0.2.1 897 0x80000002 0x00183A
10.16.1.8 10.0.2.1 897 0x80000002 0x00F953

The database, which is stored in the memory of the user access level router, contains the routes to the networks, belonging to other areas, and occupies a large amount of the router's memory. To compare the efficiency of memory usage by the routers, which use the IS-IS routing protocol, a testbed was used, the model of which is presented in Figure 11.

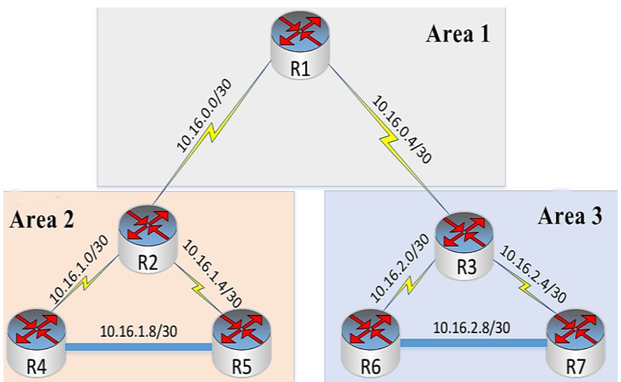


Fig. 11. The model of the data transmission testbed

As can be seen from Figure 11, routers R2 and R3, which are the level 1-2 routers, are not located on the border between two areas, but belong to a single area, though they are used for transferring data between the standard area and the backbone area. The R1 router, located in the backbone area and transferring data from one standard area into another standard area (in this case, areas 2 and 3), is located in area 1. The backbone area is present, but it doesn't necessarily have a number 0, which is reflected in the diagram of the routing testbed. The R1 router R1 is a level 2 router, the routers R4-R7 are level 1 routers and can only transfer information between directly connected devices of the same level. For the communication with devices from other areas, they need to use level 1-2 routers, which store information on the routes of the area in which they are located (level 1 routes), as well as on the routes of the backbone area (level 2 routes).

The routing table of the level 1-2 router is presented below.

r3#show ip route

10.0.0.0/8 is variably subnetted, 10 subnets, 2 masks
C 10.0.2.1/32 is directly connected, Loopback0
i L1 10.16.2.8/30 [115/20] via 10.16.2.6, Serial0/2
[115/20] via 10.16.2.2, Serial0/1
i L2 10.16.0.8/30 [115/30] via 10.16.0.5, Serial0/0
i L2 10.16.1.8/30 [115/40] via 10.16.0.5, Serial0/0
C 10.16.2.0/30 is directly connected, Serial0/1
i L2 10.16.0.0/30 [115/20] via 10.16.0.5, Serial0/0
i L2 10.16.1.0/30 [115/30] via 10.16.0.5, Serial0/0
C 10.16.2.4/30 is directly connected, Serial0/2
C 10.16.0.4/30 is directly connected, Serial0/0
i L2 10.16.1.4/30 [115/30] via 10.16.0.5, Serial0/0

The topology table of the area border router contains entries of 10 networks, the same as the topology table for a similar testbed, using the OSPF routing protocol. In addition to the information on the available networks and routes, through which they are available, there is also information on the level of the topology table, in which the information data is stored; this is indicated by the code symbols L1 and L2.

The routing table of the level 1 router is presented below.

r6#show ip route
10.0.0.0/8 is variably subnetted, 7 subnets, 3 masks
C 10.0.2.2/32 is directly connected, Loopback0
C 10.16.2.8/30 is directly connected, FastEthernet0/0.421
C 10.16.2.0/30 is directly connected, Serial0/0
i L1 10.16.2.4/30 [115/20] via 10.16.2.10, FastEthernet0/0.421
[115/20] via 10.16.2.1, Serial0/0
i L1 10.16.0.4/30 [115/20] via 10.16.2.1, Serial0/0
C 10.32.2.0/28 is directly connected, FastEthernet0/1.121
C 10.32.2.16/28 is directly connected, FastEthernet0/1.122
iL1 0.0.0.0/0 [115/10] via 10.16.2.1, Serial0/0

It can be seen that the routing table contains 7 entries, which is less than in case of using the OSPF protocol; in the latter case the routing table contained 10 entries. The level 1 router only stores the information on level 1 routers, which is confirmed by the fact that only the entries with a L1 tag are present.

The database of the IS-IS protocol is also smaller than the OSPF databases. The database of the level 1-2 router is presented below.

r3#show isis database

IS-IS Level-1 Link State Database:

LSPID LSP Seq Num LSP Checksum LSP Holdtime ATT/P/OL
r3.00-00 * 0x00000006 0x64D9 577 1/0/0
r6.00-00 0x00000005 0x9265 518 0/0/0
r7.00-00 0x00000005 0x7627 626 0/0/0
IS-IS Level-2 Link State Database:
LSPID LSP Seq Num LSP Checksum LSP Holdtime ATT/P/OL
r1.00-00 0x00000005 0x90A6 658 0/0/0
r2.00-00 0x00000007 0x15AC 407 0/0/0
r3.00-00 * 0x00000007 0x7399 697 0/0/0

It should be noted that the database is smaller than the OSPF database and contains records of not all the routers in the network, but only those which belong to the same area as the level 1-2 router, and also of the level 2 router and the channels of communication with it.

The database of the level 1 router is presented below.

r6#show isis database

IS-IS Level-1 Link State Database:
LSPID LSP Seq Num LSP Checksum LSP Holdtime ATT/P/OL
r3.00-00 0x00000006 0x64D9 344 1/0/0
r6.00-00 * 0x00000006 0x9066 1046 0/0/0
r7.00-00 0x00000005 0x7627 396 0/0/0

It should be noted that the level 1 router only stores information on the routers of the same level (R6 and R7), located in the same area, as well as on the level 1-2 router (R3). Thus, the database of the user access level router, which uses the IS-IS routing protocol, occupies a much smaller amount of memory than the database of the router, using the OSPF routing protocol.

B. *Conclusions of the efficiency of use*

When considering IS-IS protocol, it is necessary to remember that in many aspects it is similar to OSPF-protocol and, besides it is routing protocol by the channel status, it uses Dijkstra's algorithm of searching for the shortest way, mailing the packages on the channels status and many others. At that, there are many differences between routing protocols IS-IS and OSPF, first of all because the IS-IS is not using IP-addresses as the routs. On the one hand, it allows to use IS-IS-protocol for operating in IPv6 networks, where OSPF version 2 is not capable to do that, and to resolve this problem, the OSPF-protocol version 3 has been developed. However, on the other hand, when using IPv4, adjusting routing by means of IS-IS-protocol will cause necessity to study sufficient volume of information and to use unusual methods of routing adjustment.

VI. CONCLUSION

Having considered several options of modernization, including the revolutionary one – changing OSPF-protocol for IS-IS-protocol, and evolutionary one – changing parameters of OSPF-protocol, like: use of route information redistribution; use of dead-end zones; use not completely dead-end zones. It is necessary to make a conclusion on all pluses and minuses of the reviewed options of modernization and choose the best one among presented (Table 11).

All the options of existing routing system modernization have in common that all reviewed option allow to reduce the tables of routing being stored in memory of the routers located inside regular zones. Thus, the conclusion can be made that any of the reviewed options allows to resolve the main problem and to reduce load on the routers.

Rest of advantages are not that valuable to make a choice of their basis. To select the modernization option, it is necessary to review the disadvantages inherent to various options.

TABLE XI. THE PARAMETERS OF THE DEFAULT-INFORMATION ORIGINATE COMMAND

Option of modernization	Advantages	Disadvantages
Use of route information redistribution	Reduction of the tables of topology and occupied by them memory volumes in the inner routers. Possibility to conduct the modernization on existing equipment.	Complicated adjustment of the routing mechanism on the transport-peripheral nodes and on the regional node.
Use of completely dead-end zones	Simplicity of completely dead-end zones adjusting. Possibility to use completely dead-end zones on the existing equipment.	Impossibility to add statistics routes inside the completely dead-end zones. Impossibility to use border routers of autonomous systems in the dead-end zones.
Use of not completely dead-end zones	Reduction of the tables of topology and occupied by them memory volumes in the routers memory. Possibility to transfer external routs from not completely dead-end zone.	Possible discrepancy between standards of the equipment operational systems. There is a danger that the installed equipment will not be possible to set for joint operation.
Use of routing protocol IS-IS	Reduction of the routing tables and data bases, therefore - occupied by them memory volumes in the router memory. Possibility to use in large data transfer networks. Easy scaling the existing network.	Difficulty to set routing in the data transfer network using UPv4 addressing. Impossibility to establish communication between the routers of level 1 and level 2 without using intermediate routers of 1-2 level.

Use of route information redistribution mechanism is rather complicated thing both during setting and further operation, plus it requires high qualification of the network engineer. The mechanism of completely dead-end zones is not that complicated in setting and in operation, but it does not allow adding statistics routes within the zones neither provide communication of the regular zone with the autonomous systems, thus reducing efficiency of data transfer network. The not completely dead-end zones, having all advantages of the completely dead-end zones, allows to contain within regular zones the border routers of the autonomous systems and thus to enhance flexibility of data transfer network. The minus is that there is a necessity appearing to use equipment with a modern operational system. Change the routing protocol OSPF for IS-IS protocol. This option is rather labor intensive and it requires use of very competent personnel, meaning high labor costs.

Therefore, the most advantageous option to effect the routing scheme seems to be the option using not completely dead-end zones, which does not require much efforts on implementation and support of the network functionality, as well as increasing data transfer network flexibility and possibility to transfer information from the regular zones into other autonomous systems.

REFERENCES

[1] Kolbasinsky, D. B., 2013. Information Networks and TV Communications. Pp: 431.

[2] Makarov, S.V., V.V. Ostanin and I.V. Vaitkov, 2014. The Comparison of Routers by Firms Cisco, Juniper and Huawei. Modern Applied Science, 8(6).

[3] Al-Kasassbeh, M. and M. Adda, 2008. Analysis of Mobile Agents in Network Fault Management. Journal of Network and Computer Applications, 31: 699-711.

[4] Willie, E.C.G. and M.M. Tenorio, 2014. Considering Packet Loss in Fault-Tolerant OSPF Routing. IEEE Latin America Transaction, 12(2): 248-255.

[5] Xu, D., M. Chiang and J. Rexford, 2011. Link-State routing with Hop-by-Hop Forwarding Can Achieve Optimal Traffic Engineering. IEEE/ACM Transactions on Networking, 19(6): 1717-1730.

[6] Solie, K. and L. Lynch, 2004. CCIE Practical Studies (1st ed.). Cisco Press.

[7] Nazri, M.I. and A.M. Zin, 2008. Emulation Network Analyzer Development for Campus Environment and Comparison between OPNET Applicatio and Hardware Network Analyzer. European Journal of Scientific Research, 24(2): 270-291.

[8] Al-Kasassbeh, M. and M. Adda, 2009. Network Fault Detection with Wiener Filter-Based Agent. Journal of Network and Computer Applications, 4(32).

[9] Guo, Y., Z. Wang, X. Yin, X. Shi and J. Wu, 2014. Traffic Engineering in SDN/OSPF Hybrid Network. In Proceedings of the 22nd IEEE International Conference on Network Protocols, pp: 563-568.

[10] Guo, H., W. Su, H. Zhang and S.-Y. Kuo, 2011. On the Convergence Condition and Convergence Time of BGP. Computer Communications, 34(2): 192-199.

[11] Fengxiang, Z. and A.B.E. Shunji, 2006. A DoS/DDoS Attacks Detection Scheme Based on In/Out Traffic Proportion. Information and Communication Engineers, 105: 7-11.

[12] Pang, Q., S.C. Liew, C.P. Fu, W. Wang and V.O. Li, 2003. Performance Study of TCP Veno over WLAN and RED Router. In Global Telecommunications Conference, 2003. GLOBECOM '03. IEEE (Volume 6), pp: 3237-3241.

[13] Qu, H., Z.Yi and S.X. Yang, 2014. Efficient Shortest-Path-Tree Computation in Network Routing Based on Pulse-Coupled Neural Networks. IEEE Transactions on Cybernetics, 43(3): 995-1010.

[14] Rosenberg, E. and J. Uttaro, 2013. A Fast Re-Route Method. IEEE Communications Letters, 17(8): 1656-1659.

[15] Bouillard, A., C. Jard and A. Junier, 2014. The Impact of Initial Delays in OSPF Routing. Communication in Computer and Information Science, 456: 37-57.

[16] Altin, A., B. Fortz, M. Thorup and H. Umit, 2013. Intra-Domain Traffic Engineering with Shortest Path Routing Protocols. Annals of Operations Research, 204(1): 65-95.

[17] Thai, B., R. Wan, A. Seneviratne and T. Rakotoarivelo, 2003. Integrated Personal Mobility Architecture: A Complete Personal Mobility Solution. Mobile Networks and Applications, 8(1): 27-36.

[18] Huh, I., J.Y. Lee and B.C. Kim, 2006. Decision of Maximum Congestion Window size for TCP performance Improvement by Bandwidth and RTT measurement in Wireless Multi-hop Networks. International Journal of Information Processing Systems.

[19] Nazri, M.I. and A.M. Zin, 2008. Measurement and Characterization of Network Traffic Utilization between Real Network and Simulation Modeling in Heterogeneous Environment. International Journal of Computer Science and Network, 8(3): 326-337.

[20] Vishwanath Member, A., K. Hinton, R.W.A. Ayre and R.S. Tucker, 2014. Modeling Energy Consumption in High-Capacity Routers and Switches. IEEE Journal on Selected Areas in Communication, 32(8): 1524-1532.

An Automatic Evaluation for Online Machine Translation: Holy Quran Case Study

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***Abstract*—The number of Free Online Machine Translation (FOMT) users witnessed a spectacular growth since 1994. FOMT systems change the aspects of machine translation (MT) and the mass translated materials using a wide range of natural languages and machine translation systems. Hundreds of millions of people use these FOMT systems to translate the holy Quran (Al-Qurʾān) verses from the Arabic language to other natural languages, and vice versa. In this study, an automatic evaluation for the use of FOMT systems to translate Arabic Quranic text into English is conducted. The two well-known FOMT systems (Google and Bing Translators) are chosen to be evaluated in this study using a metric called Assessment of Text Essential Characteristics (ATEC). ATEC metric is one of the automatic evaluation metrics for machine translation systems. ATEC scores the correlation between the output of a machine translation system and professional human reference translation based on word choice, word orders and the similarity between MT output and the human reference translation. Extensive evaluation has been conducted on two well-known FOMT systems to translate Arabic Quranic text into English. This evaluation shows that Google translator performs better than Bing translator in translating Quranic text. It is noticed that the average ATEC score does not exceed 41% which indicates that FOMT systems are ineffective in translating Quranic texts accurately.**

Keywords*—*machine translation; language automatic evaluation; Statistical Machine Translation; Quran machine translation; Arabic MT

I. Introduction

The Arabic word "Quran", "Qurʾan" or "(Al-Qurʾān)" means literally "the recitation". The holy Quran is considered by Muslims around the world as the verbatim word of God (Allah) dictated by Allah through the archangel Gabriel (Jibrīl) to the Prophet Muhammad. Holy Quran is divided into 114 Sûrats (chapters). Each Sûrat consists of several number āyāts (verses). The length of these Sûrats varies considerably, where Sûrat length is measured in the number of āyāts that it has and that varies from few āyāts (verses) as in the first Sûra (Al-Fatiha) which consists of seven verses only to hundreds of āyāts within the same Quranic Sûrats such as the second Sûra (Al-Baqarah) that consists of 286 verses. The total number of Quranic verses is 6,236 [1-4].

The Quran is originally saved and written in the Arabic language. To sustain its high authenticity, translators of Quran into other natural languages strive to be consistent in terms of such translation. Nonetheless, it is known that when translating words and statements from one language to another, more than one word can be used to translate/interpret a particular word. In addition, and due to the nature of differences between the different natural languages, in many cases, word-by-word translation may not produce meaningful statements. As such, the general statement meaning or interpretation may be necessary to explain the meaning of Quran statements despite the fact that such meaning translation or interpretation may not be literal or word by word identical to the original one.

The expansion of information through the Internet gives a huge source of information to all humans worldwide to access and read information. Information can be then written in one language in one place in the world, read and translated to all other languages and places. Many information retrieval systems and search engines such as Google provide their own interpretation of information and data posted to web pages when translating text from one language to another. The correctness or accuracy of such online dictionary or language translation should then be evaluated especially when it comes to sensitive texts such as holy or religious books including the holy Quran.

The Arabic language gains interest recently due to many religious and political factors. Non-Arabic speakers still need to translate the holy Quran in order to know its meaning or to understand it. Many none Arabic-speakers use online FOMT systems to translate the holy Quran. These systems need to be evaluated to know the quality of their outputs.

The evaluation of MT systems is subjective and not objective whether it is conducted by a professional human expert or by computerized systems using metrics such as BLEU or ATEC. The quality of automatic machine translation may vary due to different algorithms used by these MT systems. The variations in the evaluation of different automatic metrics to evaluate the effectiveness of different machine translation systems is due to the following reasons. First, it may depend on the machine translation algorithms, dictionary size or correctness, or the nature of the language and the input text. The evaluation of the quality of translation by ATEC (Assessment of Text Essential Characteristics: http://mega.ctl.cityu.edu.hk/ctbwong/ATEC/ [5]) metric is based on Word choice and word position to automatically evaluate MT systems. ATEC metric is proposed by Wong and Kit and was presented for the first time in 2008 [6]. ATEC is used in this study to evaluate the effectiveness of two Well-known FOMT online systems (Google and Bing Translators).

The rest of the paper is organized as follows: Section II exhibits an overview of the related work. Section III presents the proposed methodology. Section IV exhibits the experiments, and section V presents the results of the conducted experiments on four Sûrats (Chapters) from the holy Quran which totally constitute to around 9% of the whole number of Quranic verses. Section VI presents the conclusions.

II. Related Work

The cost and speed are the main reasons that lead to the widespread and extensive use of machine translation systems. No one claims that the MT systems and their automatic evaluation are better than human professionals. However, these tools are cheaper and faster when compared with human effort and translation. The literature has a large number of papers that discussed different techniques to automatically evaluate MT systems. Some of these studies will be presented in this section.

Bi-Lingual Evaluation Understudy (BLEU) metric is one of the earliest and widespread automatic evaluation metrics which is presented in 2002 by [7]. BLEU popularity is due to the easiness of its computation. In addition, it can be considered as language independent. Many versions of this metric are presented in different studies. BLEU uses a modified unigram precision to compute the correlation between candidate and reference translations.

(METEOR: Metric for Evaluation of Translation with Explicit ORdering) (Banerjee and Lavie, 2005 [8]; Lavie and Denkowski, 2009) is a recall-oriented metric that tries to solve some of the problems in BLUE such as dealing with an exact matching of words' locations. The formula can deal with more than one reference statement for evaluation. Similar to ATEC approach, METEOR performs words' alignments when the word order in reference translations is different from word order in candidate translations.

Wong and Kit presented in their paper [6] for the first time their novel automatic metric which is called ATEC. In order to express an idea in any natural language, you have to choose the right words and put them in the right order. This simple fact of natural language research is used by Assessment of Text Essential Characteristics (ATEC). Authors Wong and Kit [5, 6] presented ATEC (F-measure oriented metric) for machine translation. As discussed earlier, ATEC metric computes the precision and recall in order to compute F-measure. Afterward, the penalty is computed which is based on the differences in word orders. The final value of ATEC is calculated by multiplying F-measure by the penalty as shown in the introduction section of this study. This is the version which is adopted in this study. The same authors of ATEC [5, 6] proposed later an enhanced ATEC version of this metric and presented an updated version of ATEC in [10]. This new metric includes word position and information flow.

The study of Al-Kabi, Hailat, Al-Shawakfa, and Alsmadi [11] uses BLEU metric to evaluate the quality of two free online translators (Google and Babylon translators) in translating English sentences to Arabic. They conclude in their study that the quality of Google translator is better than the quality of Babylon translator. Al-Deek, Al-Sukhni, Al-Kabi, and Haidar [12] conducted a study to automatically compare the translation quality of Google Translator and IM Translator) by using ATEC metric. Their results showed that Google translator outperforms IM translator in terms of the quality of translating English sentences to Arabic.

The study of Hadla, Hailat, and Al-Kabi [13] also evaluates the translation quality of two free online machine translators (Google and Babylon translators) from Arabic to English. In their study, the researchers select BLEU metric to measure the quality of translation of the two systems under evaluation. The researchers used a corpus that consists of more than 1000 Arabic sentences in their study. The result of their study also indicates that the quality of Google translator is better than the translation quality of Babylon. The corpus of Arabic sentences they used with the English translations of these sentences consists of 4169 Arabic words, where the number of unique Arabic words is 2539. This corpus is released online to be used by other researchers. These Arabic sentences were distributed among four basic sentence functions (declarative, interrogative, exclamatory, and imperative). Hadla, Hailat, and Al-Kabi extended their study in [14]. They used METEOR 1.5 and BLEU metrics to evaluate the effectiveness of Google Translate and Babylon MT systems, using 1033 Arabic sentences with two English reference translations for each Arabic sentence. A system is built to automatically evaluate MT using METEOR 1.5 and BLEU. As their previous study the Arabic sentences are distributed equally among four basic sentence functions (declarative, interrogative, exclamatory, and imperative). The results of study [14] showed clearly that the outputs of Google Translate are closer to reference translations than Babylon MT system, except in the case of translating exclamatory Arabic sentences to English where Babylon MT system outputs prove to be closer to reference translations than the outputs of Google Translate.

III. Methodology

This section presents the methodology followed in this paper to evaluate two FOMT systems. As shown in Fig. 1, the study starts with the collection of the dataset that contains the original Arabic texts of four Quranic chapters of the holy Quran, where the total number of verses of these four chapters is 486 as shown in Table I, in addition to the English translation of each collected Arabic verse of the four selected chapters. This study selects the four chapters with different lengths (i.e. number of verses in the chapter) in the holy Quran. Table I shows the number of verses in each chapter used in this study. The translated version of these Quranic chapters was collected from King Fahd Complex for the Printing of the Glorious Quran website [15].

TABLE I. The Sizes of Used Quranic Chapters

Chapter Name (AR)	Chapter Name (EN)	Number of Verses
Al-Fâtihah	The Opening	7
Al-Baqarah	The Cow	286
Al-Kahf	The Cave	110
Yâ-Sîn	YaSin	83
Total		486

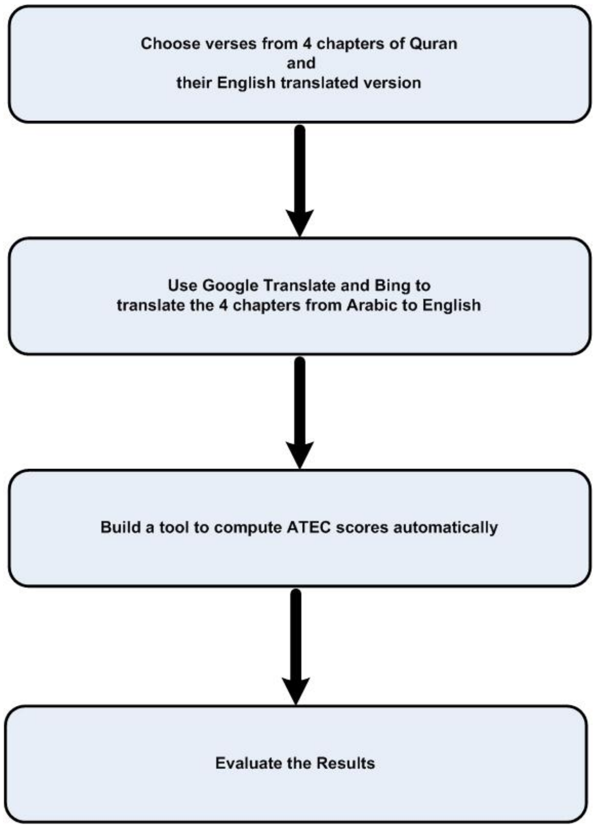

Fig. 1. Schematic overview of the methodology

As shown in Fig. 1, in the second phase of the methodology of this study, the collected Quranic verses are translated from Arabic to English using both FOMT systems under evaluation (Google and Bing Machine Translators). After translating the collected verses, ATEC scores should be computed based on the correlation between the automatically translated verses (i.e. output of FOMT systems) and those translated by professional humans (i.e. verses collected from human translated version of the Glorious Quran).

ATEC score computation is based on unigram F-measure to measure the word choice (i.e. matching between candidate and reference translations). Therefore, this metric computes Precision (P) and Recall (R) in order to compute afterward the unigram F-measure which measures word choice as shown in the following formulas 1 and 2 [6]:

$$P(c,r) = \frac{M(c,r)}{|c|} \tag{1}$$

$$R(c,r) = \frac{M(c,r)}{|r|} \tag{2}$$

Where P(c, r), R(c, r), and M(c, r) are: precision, recall and number of matched unigrams between the candidate (c) and reference translations respectively. |c| and |r| are the lengths of candidate translation and reference translation respectively.

Next unigram F-measure (F(c, r)) can be computed as shown in formula 3 [6]:

$$F(c,r) = \frac{2 \times P(c,r) \times R(c,r)}{P(c,r) + R(c,r)} \tag{3}$$

As mentioned before, this metric is based on word choice which measured as described in formula 3. Afterward, this study measures the word order in terms of penalty rate (Penalty) which is based only on word position differences between a candidate translation and one or more reference translations as shown in formula 4 [6]:

$$Penalty = \begin{cases} 1 - (PosDiff \times 4) & if \;\; PosDiff \leq 0.25 \\ 0 & if \;\; PosDiff > 0.25 \end{cases} \tag{4}$$

Afterward, the ATEC measure is computed using F-measure (formula 3) and the penalty (formula 4). Formula 5 presents the ATEC metric [6]:

$$ATEC = F(c,r) \times Penalty \tag{5}$$

ATEC score is calculated sentence by sentence and then averaged for the whole document.

To achieve the objectives of this research, a tool is built to automatically compute ATEC score for each FOMTs under evaluation (Google and Bing Machine Translators). In the last phase of this study, the results are evaluated (i.e. ATEC score for each FOMT system). The results are used as a sign to tell us about the quality of Arabic to English translation produced by each FOMT system. Moreover, the collected results are used to indicate which translator out of FOMTs under evaluation (Google and Bing Machine Translators) is better. thus, an average ATEC score is produced by computing the average of ATEC scores for all verses in each chapter for each FOMT system.

IV. Experiments

To automatically evaluate the performance of machine translation, an evaluation tool using C# is developed to compute ATEC score(s). The main screen of the tool is shown in Fig. 2. This tool produces the evaluation of the translation either for one verse (as shown in the Fig. 2) or for the complete chapter. Fig. 2 shows the evaluation of the sixth verses in Sûrat Al-Fâtihah. Fig. 2 shows clearly the values of Precision (P) and Recall (R), and ATEC score.

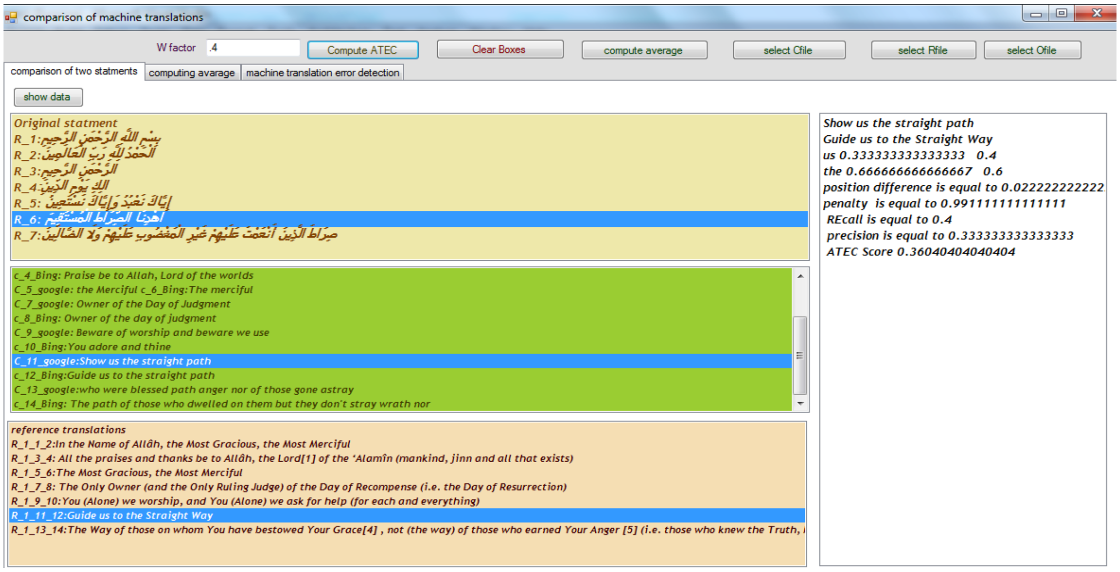

Fig. 2. The main screen of the Arabic ATEC-based FOMT Evaluation System

V. Results

To extensively evaluate the quality of FOMT systems in translating Quranic text, the experiments were conducted on four chapters. Table 2 shows initial results of these experiments. Table 2 shows a number of verses in each chapter and the average ATEC score of each FOMT system for that chapter. Average ATEC score is produced by computing the average of ATEC score of all verses in each chapter for each FOMT system). The average ATEC score represents the quality of translation on a scale from 0 (the lowest quality) to 1 (the highest quality). Table II and Fig. 3 show the average ATEC score of Google translator varies from 0.34 (in The Opening (Sûrat Al-Fâtihah) chapter) to 0.41 (in The Cow (Sûrat Al-Baqarah) chapter) and the average ATEC score of Bing translator varies from 0.23 (in The Opening (Sûrat Al-Fâtihah) chapter) to 0.34 (in The Cow (Sûrat Al-Baqarah) chapter). Thus, it is concluded that Google Translate system is better than Bing translator in translating Quranic text.

TABLE II. AVERAGE ATEC SCORE OF EACH FOMT SYSTEM

Chapter	**Average ATEC Score**	
	Google MT	**Bing MT**
The Opening, (Al-Fâtihah)	0.34	0.23
Al-Baqarah	0.41	0.34
Al-Kahf	0.34	0.29
Yâ-Sîn	0.38	0.30

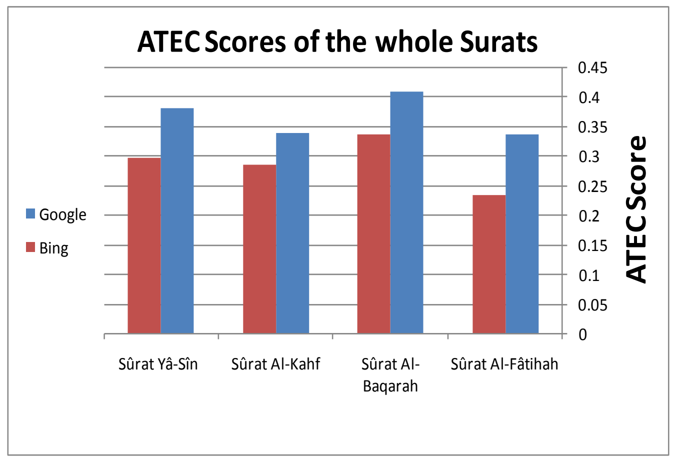

Fig. 3. Average ATEC score for each translated Sûrat on each FOMT

The results show that, although Google Translate system is better than Bing, yet the average ATEC score for both translators is less than 41% which is generally low.

In order to extensively investigate the quality of translation for both online systems, the developed tool was designed to give us the average ATEC scores for each FOMT system used to translate verses with different lengths (i.e. number of words in the translated verse). Fig. 4, Fig. 5 and Fig. 6 showed the average ATEC score for the translated verses based on their length in Sûrat Al-Baqarah, Sûrat Al-khahf and Sûrat YaSin chapters respectively.

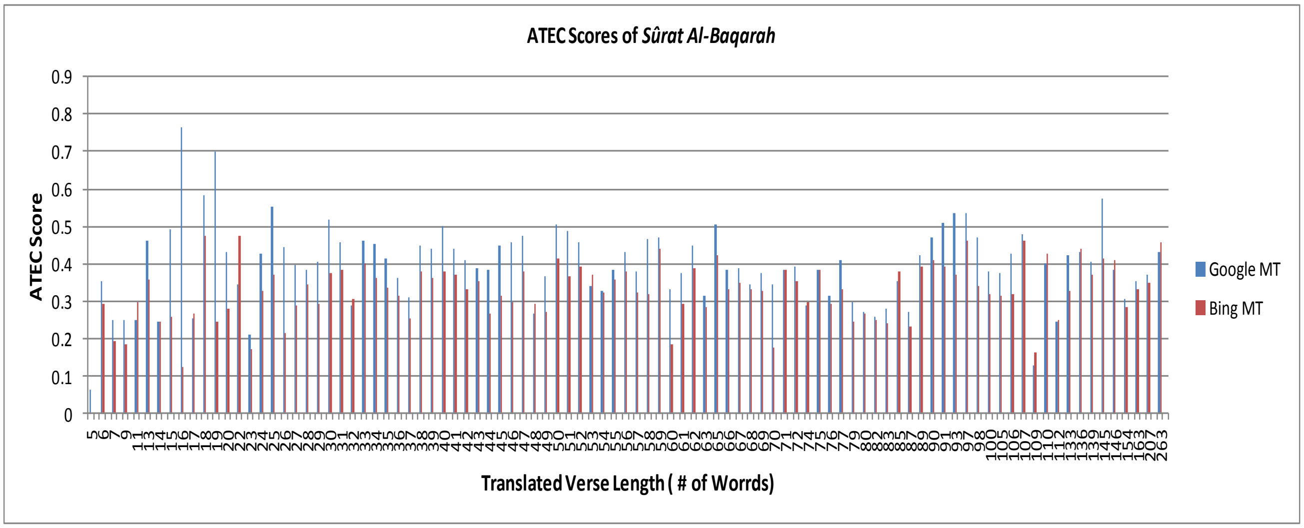

Fig. 4. Average ATEC score for different translated verses of The Cow (Al-Baqarah) chapter by the two FOMT Systems (classified by verse length)

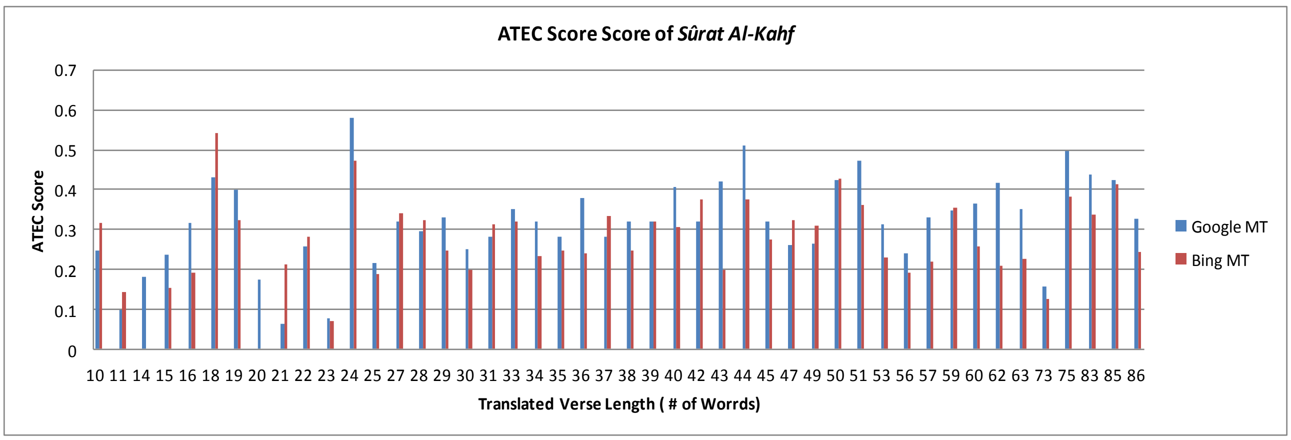

Fig. 5. Average ATEC score for deferent translated verses of Al-khahf on each FOMT (classified by verse length)

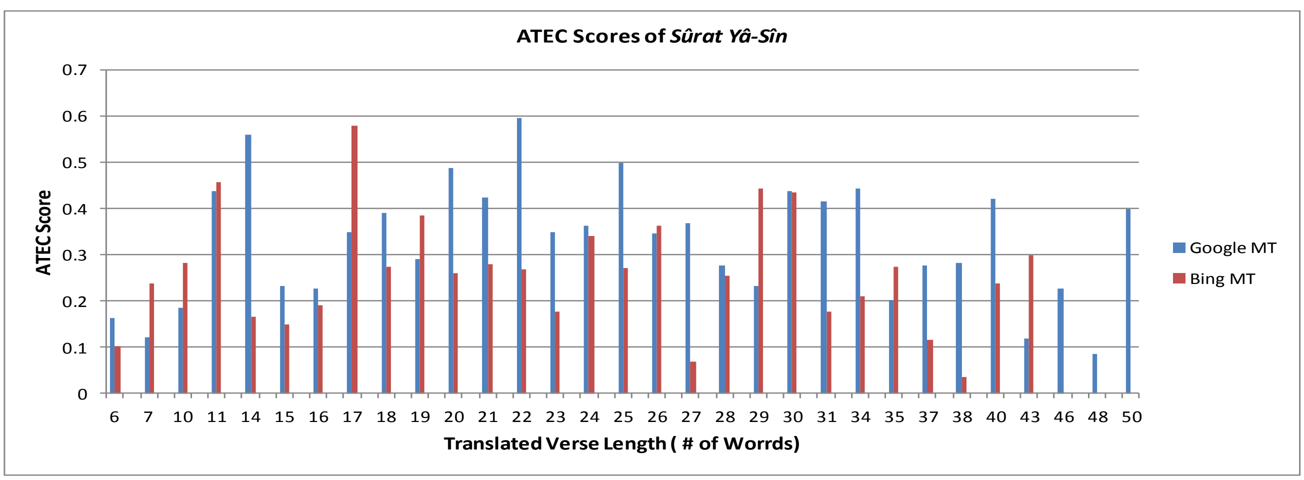

Fig. 6. Average ATEC score for deferent translated verses of Sûrat Yâ-Sîn on each FOMT (classified by verse length)

In most cases the translation of Google was better than the translation of Bing according to ATEC scores as shown in Fig. 4, Fig. 5 and Fig. 6. Moreover, from those Figures, it can be seen that the quality of the translation (which is presented by ATEC Scores) is independent of the length of the verse. The figures show that the ATEC scores of some translated verses with the short lengths are higher than the ATEC scores of some translated verses with the longer lengths and vice versa. From this observation, it is believed that the quality of verse translation is dependent on the words that composed the verse.

During the evaluation, it is found out that both FOMT systems have completely failed to translate many words (such as الأذقان(chins) and فعززنا (reinforced) in YaSin Chapter (Sûrat Yâ-Sîn), and like عسرا (distress) in (Sûrat Al-Kahf). It has also been noticed that in such cases, Google Translate System kept the word as is (in Arabic) in its translation while Bing translator used English characters to transliterate instead of translating it.

VI. Conclusion and Future Work

The need to translate Arabic text to other natural languages especially English is continuously growing. In this study, an automatic evaluation for two FOMT systems to translate Arabic Quranic text to English is conducted. The two Well-known FOMT systems: Google and Bing Translators are chosen to be evaluated in this study using ATEC. ATEC metric is one of the automatic evaluation metrics for machine translation systems. ATEC computes the correlation between the output of machine translation system and professional human reference translation based on word choice, word order, and the similarity between MT output and the human reference translation. A tool to compute ATEC score is built and used to evaluate the translation quality of the FOMT systems with a case study of four chapters of the holy Quran. The results showed that outputs of Google Translate System are better than the outputs of Bing translator. On the other hand, the average ATEC score for each translator did not exceed 41% which is generally very low especially for translating holy texts. The authors think that using look-up tables by MT systems to translate holy texts yield outputs that are fully matched with the best human translators.

As the issue of Quran translation is important to many readers and as there can be a significant difference in the meaning between “literal” and “contextual” translations, we think that a special framework and methods should be used to translate holy books in general. Our plan in future is to integrate results from automatic translations with domain experts (i.e. religious scholars). Many religious scholars for example prefer to use the word “interpretation” rather than “translation” to reflect the fact that the translation of Quran from Arabic to English or any other language can never render the exact original meanings and contexts.

References

[1] Quran. Retrieved April 01, 2013, From http://en.wikipedia.org/wiki/Quran

[2] What is Quran? Retrieved April 01, 2013, From http://www.cometoislam.com/quran.htm

[3] What is Quran? Allah describes the Quran in the Quran. Retrieved April 01, 2013, From http://www.iqrasense.com/quran/what-is-quran-allah-describes-the-quran-in-the-quran.html

[4] Islam. Retrieved April 01, 2013, From http://en.wikipedia.org/wiki/Islam

[5] B. Wong, and C. Kit, "ATEC: automatic evaluation of machine translation via word choice and word order," Machine Translation, vol. 23 No. 2-3, pp. 141–155, September 2009.

[6] B. T-M Wong, and C. Kit, "Word choice and Word Position for Automatic MT Evaluation," In Proceedings of the AMTA 2008 Workshop: MetricsMATR, 3 pages, Waikiki, Hawai'i, October, 2008.

[7] K. Papineni, S. Roukos, T. Ward, and W. J. Zhu, "BLEU: a method for automatic evaluation of machine translation," In Proceedings of the 40th Annual Meeting of the Association for Computational Linguistics (ACL 02), Philadelphia, pp. 311-318, July 2002.

[8] S. Banerjee, and A. Lavie, "Meteor: An automatic metric for MT evaluation with improved correlation with human judgments," In Proceedings of ACL Workshop on Intrinsic & Extrinsic Evaluation Measures for Machine Translation and/or Summarization, pp. 65-72, 2005.

[9] A. Lavie, and M. J. Denkowski, "The METEOR metric for automatic evaluation of machine translation," Machine Translation, 2009, vol..23, pp. 105–115, 2009.

[10] B. T-M Wong, and C. Kit, "The parameter-optimized ATEC metric for MT evaluation," In Proceedings of the Joint Fifth Workshop on Statistical Machine Translation and MetricsMATR, pp. 360-364, 2010.

[11] M. N. Al-Kabi, T. M. Hailat, E. M. Al-Shawakfa, and I. M. Alsmadi, “Evaluating English to Arabic Machine Translation Using BLEU,” International Journal of Advanced Computer Science and Applications (IJACSA), vol. 4, no. 1, pp. 66-73, 2013.

[12] H. Al-Deek, E. Al-Sukhni, M. Al-Kabi, M. Haidar, “Automatic Evaluation for Google Translate and IMTranslator Translators: An Empirical English-Arabic Translation,” The 4th International Conference on Information and Communication Systems (ICICS 2013). ACM, Irbid, Jordan, 2013.

[13] L. S. Hadla, T. M. Hailat, and M. N. Al-Kabi, "Evaluating Arabic to English Machine Translation," International Journal of Advanced Computer Science and Applications, Vol. 5, No. 11, pp. 68-73, 2014.

[14] L. S. Hadla, T. M. Hailat, and M. N. Al-Kabi, "Comparative Study between METEOR and BLEU Methods of MT: Arabic into English Translation as a Case Study," International Journal of Advanced Computer Science and Applications (IJACSA), SAI Publisher, Vol. 6, No. 11, pp. 215-223, 2015.

[15] http://qurancomplex.gov.sa/Quran/Targama/Targama.asp?TabID=4&SubItemID=1&l=eng&t=eng&SecOrder=4&SubSecOrder=1 accessed in 15/10/2013.

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Efficiency in Motion: The New Era of E-Tickets

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***Abstract*—The development of mobile applications has played an important role in technology. Due to recent advances in technology, mobile applications are creating more attraction across the world. Mobile application is a very interesting field of research. There are several ongoing research and development in both industries along with in academia. In this paper, we present the design and implementation of a mobile application that creates an electronic ticket or e-ticket application for campus police. The goals for this mobile application are to make the ticket process much faster and easier for campus police by using mobile devices. Furthermore, the results will indicate an increase in performance and productivity for campus police by sending, retrieving data, printing tickets and permits for students to limit the need for paper based ticketing.**

Keywords—Genereal; Mobile Application; Mobile Device; E-Ticket

I. Introduction

Developing mobile applications have been a hot topic in the technology world. As the mobile application market continues to grow, so does the need to support a large number of platforms to ensure applications reach the widest possible audience to provide the maximum return on investment to application owners [1]. In this technological environment, mobile applications are creating more attraction across the world. One example is the Advanced Public Safety (APS).

Today, most patrol officers can issue a moving violation with a standard multi- part ticket form in approximately ten to fifteen minutes with an electronic ticketing resolution. Patrol Officers are able to issue a ticket in two to three minutes [2]. The understanding of concepts for mobile applications has increased considerably in the last few years, thanks to ongoing research and development in technology and the academic world.

Mobile application development has become available to the general public. Ticketing agencies such as Ticketmaster and Tickets.com for entertainment and live events, sport franchises such as Major League Baseball (MLB) in the United States, and the transportation industry (air, rail, and bus) are promoting and developing mobile ticketing applications, trials and services. In addition, there is a range of vendors that work closely with these organizations to make mobile ticketing happen. [3]

Creating a mobile application can be a challenging task and can take a very long time to master the application. The mobile application approach has been the basis for many implemented programs. A simple function such as creating a button from one Java class to another Java class can be important to successfully achieve its goals. Finding patterns is an important issue and the center focus for mobile applications. Therefore, we can find a reasonable and intelligent solution to mobile applications. The complexity of global electronic ticketing solution is compounded when e-tickets are issued by different legacy based computerized reservation systems and e-tickets are stored in the database [4].

In this paper, we describe our application for designing and implementing an e-ticket based mobile application. The e-ticket mobile application described in this paper is Tigerticketz. It is designed to make the ticket process much faster and easier for campus police. Tigerticketz is a mobile application that creates an electronic report for traffic and parking regulations, and ticketing offenders. Some of the capabilities of the mobile application are to send, retrieve data, and print tickets along with permits to the students. The programming software used for the mobile application was the Android SDK with Eclipse. This software extends the capabilities of Eclipse to quickly develop new Android projects, create an application UI, add packages based on the Android Framework API, debug your applications using the Android SDK tools, and even export signed (or unsigned) .APK files in order to distribute your application [5].

The rest of the paper is organized as follows: Section 2 describes Tigerticketz Design. Section 3 defines System Architecture. Section 4 presents the Tigerticketz Algorithm. Section 5 is the Application Results and Section 6 concludes this paper with suggested recommendations for future research.

II. Tigerticketz Design

Tigerticketz Design is divided into several different layouts that interact with each other to create an application. In order to design and implement this application, some information about each of the layouts is required, which are presented in this section.

A. Main Layout

The main layout is a very important because it is the basic structure for the application. It can be considered essential for the application, where the other layouts are connected. The main layout includes textview for the Welcome text. It is an image view of a campus police logo, and four buttons that connect to four different Java classes, as shown in fig. 1. The Tigerticketz Design can be made for several different designs for a mobile application. However, it is the creator’s discretion on the choice of the design.

The design of this layout has the responsibility to maintain the rest of the layouts. The other important thing to consider is that the other layouts will add structure to the mobile application. Therefore, the creator has to decide how the mobile application's function determines the success of the application.

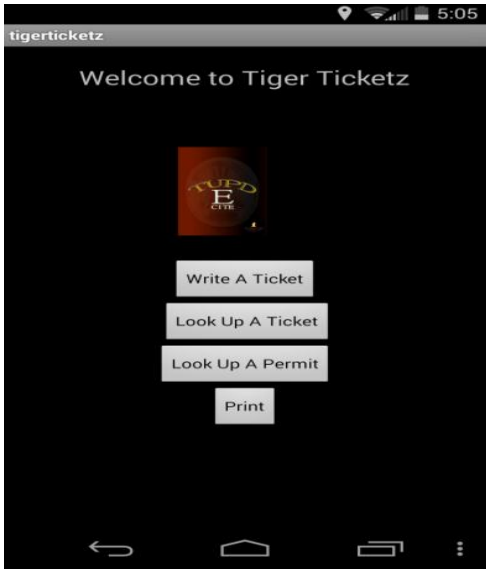


Fig. 1. Interface for Tigerticketz

B. Ticket Layout

The ticket layout is in charge of writing the tickets. In other words, it is the brains or impetus behind the application.

The ticket layout uses WebView that allow the user the ability to view web pages without opening a web browser and searching for the web page. This process makes it faster and easier for the user to access the web page with little changes as possible.

The design of this layout has the responsibility to give digital tickets for parking and permit violations. One important thing to consider is that the application must be able to connect to the Internet as well as Google Spreadsheets and Forms by authorized personnel to access the information.

C. Look up A Ticket

The lookticket layout helps the application by searching for parking and permit tickets. It is the right eye of the application's function of the application. Without this layout, it would be impossible for the application to search or retrieve tickets.

Similar to the ticket layout, lookticket layout also has the ability to view web pages. The design of this layout allows searching for tickets for parking and permit violations. Once the lookticket layout is activated by campus security, the officer can search tickets for past and present violations.

D. Look up A Permit

The permit layout helps the application by searching users that own permits. This is the left eye of the function of the application. It is similar in application to lookticket layout. Without this layout, it would be impossible for the application to search for a permit.

Similar to ticket and lookticket layout, the permit layout has the ability to view web pages. The design of this layout is in control of the look up permits to see if a user has a valid permit. Once the permit layout is activated by campus security, it can retrieve permits from the previous and current users.

E. Print

The print layout is in force behind the application. The design of this layout focuses on printout tickets for permit and ticket violations. Print layout uses ticket layout to print tickets. However, this can only be accomplished by connecting to the internet.

Similar to the rest of the layouts, the print layout uses a WebView that has the ability to view web pages. The WebView will send the user to a website that illustrates a step-by-step procedure of how to print from your tablet or smartphone device, as shown in fig. 2.

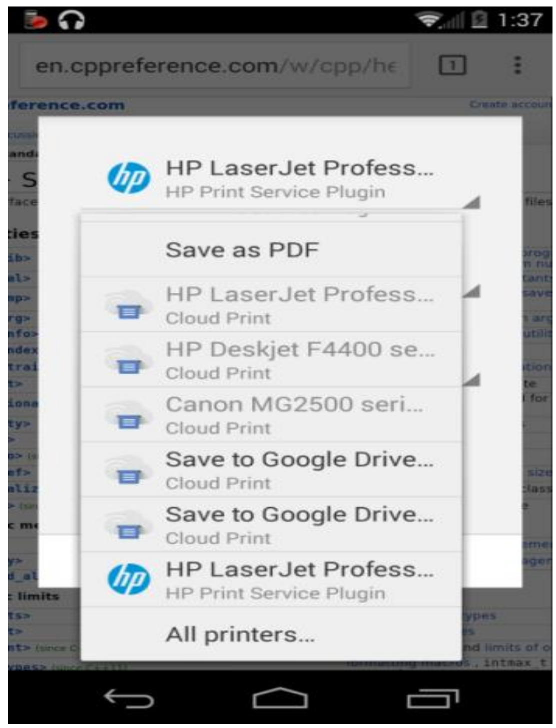


Fig. 2. Layout for Print.xml

III. System Architecture

A. Android Eclipse

It is an open source IDE (Integrated Development Environment) for Java projects and other programs. Theoretically, the open source is where the application software is crafted, and being supported through various stages of its lifecycle. Google officially supports it, and has created the Android Development Tools' plugin for Eclipse and integrated its AVD Manager virtual device management into the tool as well. [6] Moreover, a user can quickly build an Android base program, and test it through emulators that are the virtual devices that show users how the android's application runs on the android devices.

The Android offers users a plugin, which is called ADT (Android Development Tools). It is a very powerful plugin tool that integrates the environment for android development. It is an extension of Eclipse to quickly set up new android projects, create applications, and export signed and unsigned packaging. Before installing the ADT plugin, Eclipse must be installed in order to add the ADT. Some of the requirements for Eclipse to work are downloading Eclipse Indigo or greater, Eclipse JDT plugin, and JDK 6.

B. Programming Languages

Android Eclipse is written on Java code, and it is the main language for the Android, Android Eclipse and the use of other programming languages, including C, C++, Fortran, JavaScript, Perl, PHP, and Ruby. Development settings include Eclipse JDT, Eclipse CDT, and Eclipse PDT.

Java is a programming language and computing platform first released by Sun Microsystems in 1995. Several applications and websites will not work unless you have Java installed, and more applications are created every day. Java is fast, secure, and reliable from laptops to data centers, game consoles to scientific supercomputers, cell phones to the Internet, Java is everywhere! [7]

The JRE (Java Runtime Environment) contains JVM (Java Virtual Machine) which is a Java stand and a support for Java programming. The JRE also allows the users to write Java code inside the web browser. The Java plugin software is not just a standalone program. It cannot be installed in isolation.

C. Google Drive

Google Drive is a way to transform your Google Docs account into an online and offline storage system. Google Drive is basically Google Docs for the Web. It can share direct information over the web by sharing documents, folders, and files. A user is able to retrieve the Google Docs portion and have the convenience of a virtual folder on the computer, which can be simply dragged to drop files to sync between laptops, tablets, and mobile phones. [8]

Some of the features can create documents, upload documents, image, video, application and convert Microsoft office documents to Google Drive. In our mobile application, we created a Google Spreadsheet and Form for TU Vehicle Registration and the T.U.P.D. Citation Entry Form.

D. Google Spreadsheet and Google Form

Google Spreadsheets is a web-based application that allows users to create, update and modify spreadsheets and share the data online in real time. The Ajax-based program is compatible with Microsoft Excel and CSV (Comma-Separated Values) files. Spreadsheets can also be saved as HTML [9].

Google Forms is a web-based application that allows users to create, update and modify forms and share the data live online. Moreover, Google Form can create online polls and surveys.

E. Mobile Device

Mobile device is any handheld computer device. It is designed to be portable, be able to fit in the hand or hands of a user. Some mobile devices are more powerful than other devices. These mobile devices include smartphones, tablets, and watches. Mobile devices allow the user to do several things similar to desktop or laptop.

For this android application, it uses several mobile devices that were tested to make sure that the android application works properly. These devices include Samsung Galaxy Tab 2, Samsung Galaxy Tab 4, and Motorola Moto X smartphone.

1) Samsung Galaxy Tab 2

The Samsung Galaxy Tab 2 7.0 4G LTE (Version) is a 7-inch touchscreen which weighs about 12 ounces running on Android 4.0 or Android Ice Cream Sandwich operating system with a 1.2 GHz dual core processor. Ice Cream Sandwich operating system includes an Input Framework, TextureView, Switch Widget, and GridLayout. In addition, it accesses the internet and stream media over a wireless network which are needed to run the Tigerticketz app.

2) Samsung Galaxy Tab 4

The Samsung Galaxy Tab 4 is an 8-inch touchscreen which weighs about 11 ounces running on Android 4.4, KitKat, and offers 16 GB memory on the device that includes a microSD card that can go up to 64 GB memory which makes it easy to store more information. Kitkat includes updating your target API Level, Wireless and Connectivity, User Input, and Printing Framework that are very important to the success of the Tigerticketz app.

3) Motorola Moto X Smartphone

The Motorola Moto X Smartphone is a 4.7-inch touchscreen that weighs about 5 ounces running on Android 4.2.2 Jelly Bean operating system, and has the power of a 1.7 GHz dual core processor. Jelly Bean includes Lockcreen Widgets, Multiple Users, Nested Fragments, and Secondary Displays.

IV. TIGER TICKET ALGORITHM

Tigerticketz Algorithm is divided into multiple classes that interact with one other in order to create a functioning application. To implement this application, some information is needed from each class that is presented in this section.

A. Tiger Ticketz Activity

The Tiger Ticketz Activity is a class that connects to all of the other classes in the application. This is the most important class in the Tiger Ticketz application, because without this class it is physically impossible to connect to other classes in this application.

The Tiger Ticketz Activity includes an icon that represents a push of a button widget. A button can be pressed or clicked on, when the user touches the application button to perform an action or actions dependent on the event. In this application, buttons are used to connect to other classes in the application by using onClick and Intent.

OnClick is a method that is called when a view or event has been clicked. Intent is an abstract that sketch an operation that is going to be performed. For this application, the startActivity is used to launch an Activity from one class to another class. The Algorithm 1 labeled, “Tiger Ticketz”, displays the code of the Tiger Ticketz Activity class presented in fig. 3.

```
@Override
public void onCreate(Bundle savedInstanceState) {
final Context context = this;
super.onCreate(savedInstanceState);
setContentView(R.layout.main);
final Button
interb=(Button)findViewById(R.id.button1);
final Button
ticketb=(Button)findViewById(R.id.button2);
final Button
permitb=(Button)findViewById(R.id.button3);
final Button
printb=(Button)findViewById(R.id.button4);
//Ticket Button listener
interb.setOnClickListener(new OnClickListener()
{
public void onClick(View v)
{
//Start Ticket Activity
Intent intent = new Intent(context,
TicketActivity.class);
startActivity(intent);
}
});
//Ticket Search Button listener
ticketb.setOnClickListener(new OnClickListener()
{
public void onClick(View v)
{
//Start LookTicket Activity
Intent intent = new Intent(context,
LookTicketActivity.class);
startActivity(intent);
}
});
//PermitSearch Button listener
permitb.setOnClickListener(new OnClickListener()
{
public void onClick(View v)
{
//Start PermitSearch Activity
Intent intent = new Intent(context,
PermitSearchActivity.class);
startActivity(intent);
}
});
//Bluetooth Print Button listener
printb.setOnClickListener(new OnClickListener()
{
public void onClick(View v)
{
//Start LookTicket Activity
Intent intent = new Intent(context,
BluetoothPrint.class);
startActivity(intent);
}
});
}
}
```

Fig. 3. Algorithm 1. Tiger Ticketz Activity Code

The Intent runs a facility for execution delay runtime between the different types of code for different types of application at once. The most important use is to launch an activity or activities, where it can pass data that can perform an action where Tiger Ticketz Activity's structure is based upon.

B. Ticket Activity

The Ticket Activity is a class that connects the classes with layouts. This class has the responsibility of digital tickets for parking and permit violation.

The Tiger Activity includes WebView, which we mentioned earlier, gives the user the ability to view web pages without opening a web browser and searching for the web page. The WebSettings' objective maintains the usage to control the basic settings for the WebView. The WebView runs no browser widgets, with the goal to display web content.

In addition, if the user needs an actual full web browser, then, the creator can invoke the browser application with URL intent. In this application, we used the URL intent by startactivity from the class to Google Spreadsheet, as shown in fig. 4.

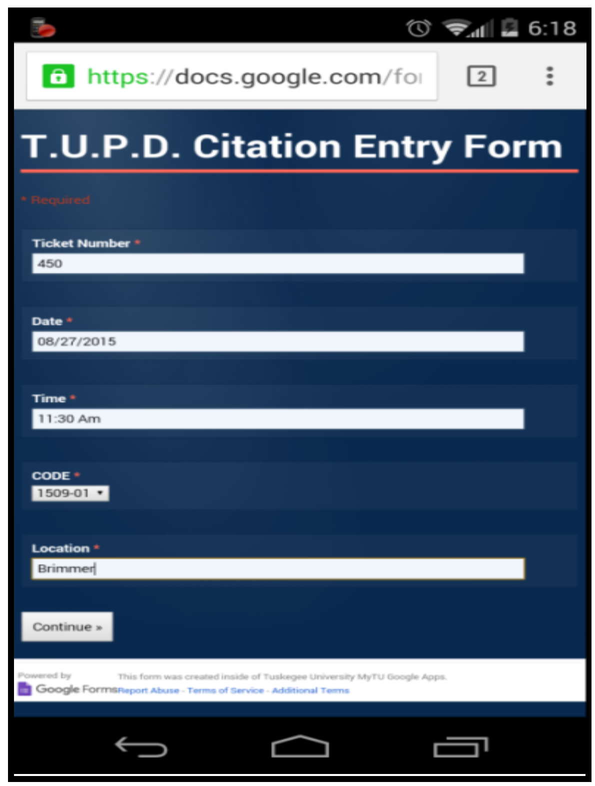


Fig. 4. Start activity from the class to Google Spreadsheet

C. Look Ticket Activity

The Look Ticket Activity is a class that connects classes with layouts. This class assists with searching for parking and permit tickets. The Look Ticket Activity includes Web View and setJavaScriptEnabled that enables or activates JavaScript. Another goal of WebView is to allow the user to display some web content without interacting with the web page outside of reading the content.

D. Permit Search Activity

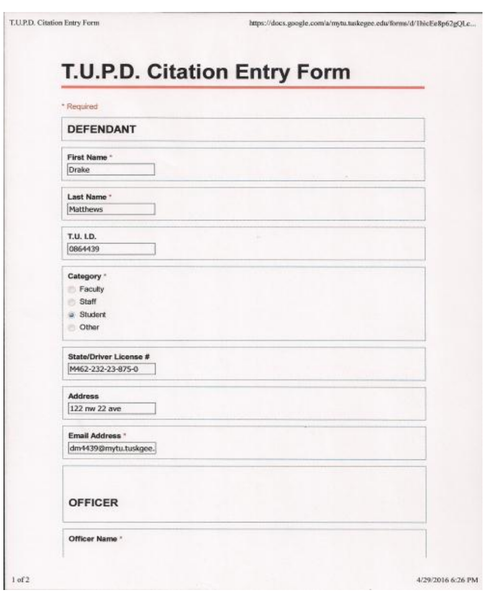
The Permit Search Activity is a class similar to the rest connecting classes with layouts. This is a class that can retrieve permits for users with valid permits. The Permit Search Activity includes WebView and loadUrl that loads the given URL that the creator places in the class.

E. Print Tutorial Activity

The Print Tutorial Activity is the last class of this application. This is a class that shows the user how to setup the application on their mobile device to printout content. The Permit Search Activity includes WebView that will link to a site that shows the user a built-in printing function that can connect to a printer that allows the user to print from Google Drive by using the Google Chrome web browser.

V. Experimental Results

We used an android mobile device to test our algorithm, and to make sure that the application works with all of the layouts and classes. We used three android mobile devices, which are Samsung Galaxy Tab 2, Samsung Galaxy Tab 4, and Motorola Moto X Smartphone to test all the functions of the Tigerticketz's application. This experiment was created to test our application, and to see if it is an usable and reliable tool for campus police. Many trials and tests were completed to figure out the best practices for writing tickets, retrieving tickets, searching permits, and printing tickets. This application is best suited to accomplish these tasks on newer android mobile devices where print functions can be easy used rather than creating code from scratch. Currently, the application can only work if an authorized user is connected to the internet to retrieve Google Spreadsheets and Forms to access the information. Moreover, users need to activate the Google Chrome web browser in order to print a ticket. The good news is that the code can be easily adjustable when a user is trying to make the layouts or even classes for Android Application. The experimental results reveal that our mobile application can be used by campus police to write tickets, retrieve tickets, search for a permit, and print tickets, as illustrated in fig. 5.


T.U.P.D. Citation Entry Form https://docs.google.com/a/mytu.tuskegee.edu/forms/d/1hicEe8p62gQLc...

T.U.P.D. Citation Entry Form

* Required

DEFENDANT

First Name *
Drake

Last Name *
Matthews

T.U. I.D.
0864439

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Staff
Student
Other

State/Driver License #
M462-232-23-875-0

Address
122 nw 22 ave

Email Address *
dm4439@mytu.tuskgee.

OFFICER

Officer Name *

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Fig. 5. Result of Print Function for Citation

VI. Conclusion and Future Work

In this paper, we designed, created, and programmed a mobile application using a wide variety of classes and layouts to write tickets, retrieve tickets, search for permits, and print tickets. Initially, it was a bit of a struggle, but the application was successful. The application should not have any problems accomplishing these tasks with different types of android mobile devices with internet access and a printer. However, it may present future challenges in a real world scenario, since not all locations on campus have an internet connection or Wi-Fi. This suggests that users are not able to access the application. Moreover, the print function may not work on all android mobile devices, and the user will need to be near a printer with a Wi-Fi connect in order to print tickets in the application. Further research and application testing with Tigerticketz will involve improving the design by making the application more user-friendly, using a wireless portable printer, using Bluetooth instead of based printers, creating or changing the database from Google Drive, and implementing the application to give users access to the application with or without the internet.

VII. Acknowledgment

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References

[1] Oliveiro-Priestnall,Darren."mobileapps_whitepaper." www.redskiessoftware.com.2011. http://www.redskiessoftware.com/content/mobileapps_whitepaper.pdf.

[2] Safety,AdvancedPublic.http://www.aps.us.2008. http://www.aps.us/landingpage/whitepaper/white_paper_download.shtml.

[3] Wilcox,Howard."MobileTicketingWhitepaper." http://www.betterticketing.com.2010. http://www.betterticketing.com/articles/MobileTicketingWhitepaper.pdf.

[4] Sawant,LakshmiNarasimhan&Nitin."tt-aa-wp-1." http://www.hexaware.com. 2006. http://hexaware.com/casestudies/tt-aa-wp-1.pdf.

[5] Android.ADTPluginReleaseNotes.2015. http://developer.android.com/tools/sdk/eclipse-adt.html.

[6] Electronicsweekly.Whatis…AndroidEclipse?2012. http://www.electronicsweekly.com/blogs/eyes-on-android/what-is/android-eclipse-2012-01/.

[7] Oracle. What is Java technology and why do I need it? 2015. https://java.com/en/download/faq/whatis_java.xml.

[8] Karch,Marziah.WhatIsGoogleDrive?2015. http://google.about.com/od/d/a/What-Is-Google-Drive.htm.

[9] TechTarget.Google Spread sheetsde finition.2006. http://searchsoa.techtarget.com/definition/Google-Spreadsheets.

Detection of SQL Injection Using a Genetic Fuzzy Classifier System

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***Abstract*—SQL Injection (SQLI) is one of the most popular vulnerabilities of web applications. The consequences of SQL injection attack include the possibility of stealing sensitive information or bypassing authentication procedures. SQL injection attacks have different forms and variations. One difficulty in detecting malicious attacks is that such attacks do not have a specific pattern. A new fuzzy rule-based classification system (FBRCS) can tackle the requirements of the current stage of security measures. This paper proposes a genetic fuzzy system for detection of SQLI where not only the accuracy is a priority, but also the learning and the flexibility of the obtained rules. To create the rules having high generalization capabilities, our algorithm builds on initial rules, data-dependent parameters, and an enhancing function that modifies the rule evaluation measures. The enhancing function helps to assess the candidate rules more effectively based on decision subspace. The proposed system has been evaluated using a number of well-known data sets. Results show a significant enhancement in the detection procedure.**

Keywords*—*SQL injection; web security; genetic fuzzy system; fuzzy rule learning

I. Introduction

Web applications are vulnerable to numerous attacks. SQL injection is a widely common threat, which remains on top of the list of web application attacks as ranked by OWASP (the Open Web Application Security Project) [1]. Various techniques of SQL injection are used by hackers to achieve different purposes: bypassing a login system, modifying a table in a database, shutting down SQL server, getting database information from the returned error message, or executing stored procedures [2].

SQL injection attacks are a type of vulnerability that is ultimately caused by insufficient input validation. Such attacks occur when data provided by the user is not properly validated and included directly in an SQL query. By leveraging these vulnerabilities, an attacker can submit SQL commands directly to the database. Web applications are threatened by this kind of vulnerability that uses user input to form SQL queries to access an underlying database [3]. Generally, SQL injection attacks are classified into seven types: tautologies, illegal/logically incorrect queries, piggy-backed queries, stored queries, inference and alternate encodings [2] [4] [5].

Attackers continuously develop new ways to bypass controls added by developers. In the recent years, hackers started to use different styles to perform SQLI. Hackers developed techniques to bypass web application firewall (WAF bypassing). The security agents started to use buffer overflow methods and applied new bypassing methods like special characters bypassing. The various types of injections at different levels require a solution that can cope with such changes.

A number of approaches address detection of SQLI attacks. Such approaches include static analysis, dynamic analysis, and combined approach. Researchers developed other approaches like mutation based approach, query tokenization and applying regular expressions. These approaches suffer from a number of problems preventing them from being the optimal solutions [6]. Those techniques lack flexibility and scalability; they cannot deal with unknown types or larger ranges of injections [7]. Lack of learning capabilities is a vital problem. Most solutions parse user input and confirm match limited to fixed and very small patterns, which are modeled by reference to existing malicious web code. However, there are new malicious web codes which can deliberately be developed to avoid being matched with the registered patterns [8]. The available parsing techniques can also cause high computational overhead affecting real-time detection [9].

Recently, machine learning techniques are adapted to overcome previously mentioned problems as they can give leverage for the broader range of malicious web code and can be adapted to variations and changes [8]. Machine learning techniques explore the study and construction of algorithms that can learn from and make predictions on data. Such algorithms operate by building a model from example inputs in order to make data-driven predictions or decisions, rather than following strictly static program instructions [10]. Some existing machine learning techniques suffer from high computational overhead; the training of classifiers in those techniques is time-consuming and causes computational overhead. Furthermore, a number of existing solutions lack adaptation capability to detect new attacks [9].

Uncertainty and fuzziness are popular phenomena in applications of machine learning. Different types of uncertainty can be observed: (i) Noise, outliers, and errors affect the input data. A machine learning method has to deal with this type of fuzzy information, showing robustness with respect to such disturbances. (ii) Distribution and fuzziness influence representation of information within a machine learning system. According to these different locations and goals of fuzzy information, a variety of different models exist which allow machine learning to deal with uncertain information as input, output, or internal representation [11]. Fuzzy rule-based systems (FRBSs) are well-known methods within soft computing, based on fuzzy concepts that address complex real-world problems. They are powerful methods to address uncertainty, imprecision, and non-linearity [12].

Fuzzy rule-based classification systems (FRBCSs) are specialized in handling classification tasks. A main characteristic of classification is that the outputs are categorical data. Therefore, in this model type, we preserve the antecedent part of linguistic variables and change the consequent part to be a class C_j from a pre-specified class set $C = \{C_1,.......,C_M\}$. FRBCS aim at representing the knowledge of human experts in a set of fuzzy IF-THEN rules. Instead of using crisp sets as in classical rules, fuzzy rules use fuzzy sets. Rules were initially derived from human experts through knowledge engineering processes. However, this approach may not be feasible when facing complex tasks or when human experts are not available. An effective alternative is to generate the FRBCS model automatically from data by using learning methods. FRBCSs have demonstrated their ability to handle control problems, modeling, classification or data mining in a huge number of applications [13].

The automatic definition of FRBCS rules can be seen as an optimization problem. Genetic Algorithms (GAs) are global search techniques with the ability to explore a large search space for suitable solutions only requiring a performance measure. In addition to their ability to find near optimal solutions in complex search spaces, the generic code structure and independent performance features of GAs qualifies them to incorporate a priori knowledge. In the case of FRBCSs, this a priori knowledge may be in the form of linguistic variables, fuzzy membership function parameters, fuzzy rules, number of rules (Genetic rule learning), etc. These capabilities extended the use of GAs in the development of a wide range of approaches for designing FRBSs over the last few years. Therefore, GAs remain today as one of the fewest knowledge schemes available to design and optimize FRBCSs with respect to the design decisions. According to the performance measures, decision makers decide which components are fixed and which need to change [13].

In this work, we investigate the FRBCS technique for detection of SQLI; we suggest a new technique to address the uncertainty, fuzziness and adaptation problems associated with existing machine learning techniques. The rule selection mechanism in FRBCS induces competition among rules by only considering the quality of matching performed by each rule. To increase the generalization power of the classifier, we have proposed a genetic fuzzy approach that creates more cooperative rules in the final population. The proposed system uses genetic algorithm (GA) for optimizing the FRBCS technique to enhance its learning and adaptation capabilities.

The rest of the paper is organized as follows: Section 2 discusses related work reported in the literature. An overview of the proposed fuzzy genetic system is explained in Section 3. The experimental result and evaluation of the proposed system are discussed in Section 4. Finally, in Section 5 the conclusion and future research directions are presented.

II. Literature Review and Related Work

In general, SQL injection attacks can be divided into the three main categories: in-band, out-of-band and inferential [14]. In the in-band attacks, the information is extracted from the same channel that is used for the attack. For example, the list of users will appear in the current page. In out-of-band attack, the extracted information is sent back to the attacker using another channel such as email. For inferential, which is also known as a blind injection, no data is sent back directly to the attacker. However, the attacker can reconstruct the data by trying the different attacks and observing the behavior of the web application.

In the literature, SQLI detection techniques can be classified into the dynamic analysis, static analysis, combined approach, machine learning, and other approaches (e.g. Hash technique, Black Box Testing) [3][15-19]. Static analysis checks whether every flow from a source to a sink is subject to an input validation and/or input sanitizing routine [20]; whereas dynamic analysis is based on dynamically mining the programmer's intended query structure on any input and detects attacks by comparing it against the structure of the actual query issued [21].

AMNESIA, as a combined approach, is a model-based technique that combines the static and dynamic analysis for detection and prevention of SQLI attacks [3]. In the static phase, to build the models of the SQL queries that are generated at points of access to the database, AMNESIA uses a static analysis. In the dynamic phase, AMNESIA intercepts all the SQL queries before they are sent to the database and checks each query against the statically built models. Queries that violate the model are identified as SQLI attacks. The accuracy of AMNESIA depends on the static analysis stage. Unfortunately, certain types of complicated codes and/or query generation techniques make this step less precise and generate both false positives and negatives [22].

As mentioned above, several approaches for detection of SQL injection were developed. The literature survey emphasizes on the machine learning techniques which are relevant to our proposed system. Valeur et al. [23] proposed an intrusion detection system capable of detecting a variety of SQL injection attacks. Profiles of normal access to the database are built using statistical methods. At runtime, queries that do not match any built model are identified as a possible attack. As with most learning-based anomaly detection techniques, the system requires a training phase prior to detection. The main problem of this technique besides the false positives and negatives is its execution and storage overhead, due to difficulty in training on all the possible normal benign queries with normal behavior [24].

In [9], the authors proposed an SQLI detection technique in adversarial environments by K-centers. They introduced a new online learning technique in which samples are learned one by one, and as a result, number and centers of the clusters are adjusted accordingly. Therefore, the K-centred technique can adapt to different kinds of attacks. The experimental results show that their method has a satisfying result on the SQLI attacks detection in the adversarial environment. The main drawback of their method is that it must receive a true label of each statement after classification [25]. The concept of pattern classifiers to detect injection attacks and protect web applications is introduced in [24]. HTTP requests are captured and converted into numeric attributes. Numeric attributes include the length and the number of keywords of parameters. Using these attributes, the system classifies the parameters by Bayesian classifier to judge whether the parameters are injection patterns or not. The main drawback is that the system depends on limited types of features.

The major contributions of the work in [26] are the proposal of a novel method based on the genetic algorithm applied to SQLI attack detection task and correlation of a number of detection tools altogether with the novel method. In this work, the authors prove that correlating several sources of information and then performing reasoning on the correlated information can improve the results of attacks detection. The main disadvantage of this algorithm is the overhead in performance and storage caused by the correlation approach.

The implementation of Artificial Neural Networks (ANN) as a biologically inspired computing is investigated in [2] to detect SQLI attacks. Multilayer Feed forward Networks (MLN) was used in the implemented system. It has the ability to learn and store the empirical knowledge, the nonlinearity nature of the neural networks, the ability to generalize the solutions and to adapt when the context changes, and suitable computational performance. The limitations include depending on the appearance of certain SQL keywords along with suspicious characters without considering the relative order between them. For this reason, despite the different order of the keywords, if a normal signature contains many keywords and suspicious characters that often appear together in an SQLI, it is highly likely to be misclassified. Another work, related to ANN-based SQLI detection, is introduced in [27, 28]. It depends on limited SQL patterns for training so it is susceptible to generate false positives.

TF-IDF has been used in [8] for weight calculation of tokens to evaluate the performance of three machine learning approaches: SVM, Naive-Bayes, and K-NN. This method has low computation time complexity but susceptible to generating false positives [9]. Furthermore, Gene Expression Programming (GEP) for detection of SQLI is discussed in [29]. At the beginning, chromosomes are generated randomly. Then, in each iteration of GEP, a linear chromosome is expressed in the form of expression tree and executed. The fitness value is calculated and termination condition is checked. The best individual is preserved through the next iteration. Afterward, the populations are subjected to genetic operators with defined probability. New individuals in temporary population constitute the current population. Classification accuracy received from GEP depicts great efficiency for SQL queries constituted from 10 to 15 tokens. For longer statements, the averaged FP and FN is approximately 23%.

Among the approaches, genetic algorithm for detection of SQLI is proposed in [30]. In this technique, levels of SQLI are detected using template matching. The ultimate goal of the genetic algorithm is to optimize the matching rules of SQLI queue in the template library. These rules are in the form of IF (condition) THEN (execution); where conditions refer to attack sequence matches. However, the algorithm relies on template sequence to define SQLIA. Therefore, the system fails to detect the attacks of different sequences that are not included in the template library.

The main objective of this paper is to propose a combined approach where FRBS and the genetic algorithm can be used together to improve the accuracy of the system for detection of SQLI, consequently, new SQLI attacks can be processed and detected. To the best of our knowledge, there is no previous work that uses FRBS for detecting SQLI attacks. To enhance the accuracy of learning capability, we extend FRBS with the genetic algorithm to find the most suitable rules for FRBCS.

III. Proposed SQL Injection Detection System Using Fuzzy Genetic

This paper introduces a GA based method to generate a fuzzy rule base for SQLI detection. With the specific structure of the chromosome, the GA operations and the adequate fitness function, the proposed method produces a fuzzy rule base (FRB) with proper rules. Designers usually cannot guarantee that the fuzzy control system designed with trial-and-error for building fuzzy rules has a reliable performance. Fig. 1 illustrates the flow diagram of the proposed system.

In this work, the fuzzy rule base is tuned automatically by GA, known as Genetic Fuzzy System (GFS). The fuzzy logic produces controllers that are suitable for dealing with uncertainty and imprecision. Second, fuzzy behaviors can be conveniently synthesized by a set of IF-THEN rules using easy-to-understand linguistic terms to encode expert knowledge. Finally, the interpolative nature of fuzzy systems helps express partial and simultaneous simulations of SQLI features, and the smooth transitions between these features [30].

GA starts with a population of randomly generated chromosomes, and advance towards better chromosomes by applying genetic operators inspired by the genetic process occurring in nature. The population undergoes evolution in a form of natural selection. During successive iterations, called generation, chromosomes in the population are evaluated for their adaptation as solutions, and on the basis of this evaluation, a new population of chromosomes is formed using a selection mechanism, crossover, and mutation operators. A fitness function must be devised for each problem to be solved. Each chromosome is evaluated using the fitness function, returning a single numerical value. The probability of selection of a certain chromosome is directly proportional to its fitness function [31]. A GA-tuned fuzzy system with seven inputs and one output will be illustrated to explain the SQLI detection process.

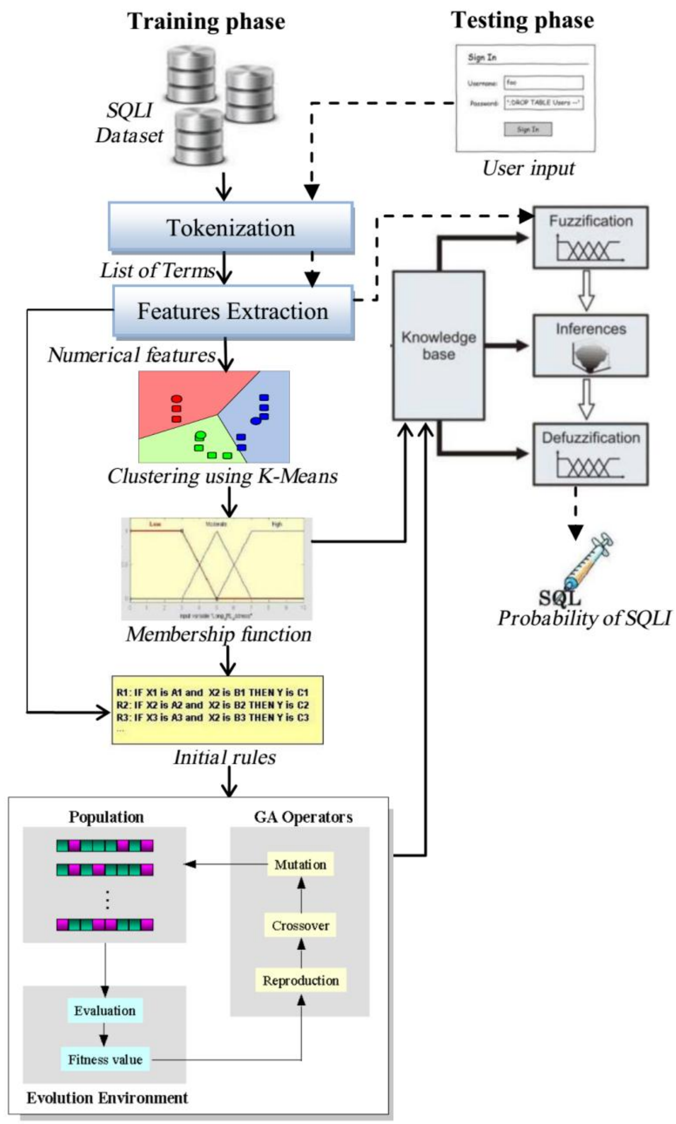

Fig. 1. Proposed SQL Injection Detection System

A. *Extracting SQLI features from dataset*

The SQLI attack keywords are the popular keywords in SQL language which are generally used in order to perform operations on the tables inside a given SQL database. This approach extracts tokens (keywords) which consist of specific terms of malicious web code as features. Tokenization is a process of breaking a sentence into a list of words. In other words, a tokenizer parses a sentence into a list of tokens. Based on these tokens, the system extract the features, and represent each query as a sequence of numbers, each number represents one of the features mentioned below [2] [8] [9] [27] [26].

- f_1 : Frequency of special characters (dangerous characters) like (--, #, /*, ', ", ||, \\, =, /**/,@@).
- f_2 : Frequency of special tokens (dangerous tokens) like (rename, drop, delete, insert, create, exec, update, union, set, Alter, database, and, or, information_schema, load_file, select, shutdown, cmdshell, hex, ascii).
- f_3 : Frequency of punctuations like (<, >, *, ; , _, -, (,), =, {, }, @, ., , &, [,], +, -, ?, %, !, :, \, /).
- f_4 : Frequency of SQL tokens like (where, table, like, select, update, and, or, set, like, in, having, values, into, alter, as, create, revoke, deny, convert, exec, concat, char, tuncat, ASCII, any, asc, desc, check, group by, order by, delete from, insert into, drop table, union, join).
- f_5 : Length of SQL statement.
- f_6 : Frequency of spaces within the parameter of the query, which leads to the possibility of attacks.
- f_7 : Existence of statements that always result in true value, for example "1=1" or "@=@" or "124=124".

The appropriate selection of these features plays a crucial role in several aspects of the design of robust and feasible SQLI detection systems. The rationale for choosing these types of features is its ability to identify most of SQIA types like tautologies, union, piggybacked, illegal/logically incorrect, alternate encodings and stored procedures which are treated the same as SQL queries. Other features can be included to increase the scalability of the system to detect new malicious code. In addition, by reducing the number of features (by eliminating redundant or irrelevant features), the performance of rule induction system can be improved as well as the classification performance of the rules produced.

B. *K-means clustering*

To transfer the extracted numerical features (all mentioned above features except the 7th feature into linguistic terms low (*L*), medium (*M*) and high (*H*); the system utilizes K-means clustering algorithm. k-means is one of the simplest unsupervised learning algorithms that solve the well-known clustering problem. The procedure follows a simple and easy way to classify a given data set through a certain number of clusters (assume *k* clusters) fixed Apriori. Let $X=\{x_1,x_2,...,x_n\}$ be the set of data points, that represents the $f_i(i=1,...6)$ values across the queries and $V=\{v_1,v_2,...,v_n\}$ be the set of initial centers. Algorithmic steps [32, 33] for *k*-means clustering are:

1) Randomly select k cluster centers, k =3 in our case.

2) Calculate the distance between each data point and cluster centers.

3) Assign the data point to the cluster center whose distance from the cluster center is the minimum of all the cluster centers.

4) Recalculate the new cluster center:

$v_i=\left(\frac{1}{c_i}\right)\sum_{j=1}^{c_i}x_i$, where c_i represents the number of data points in i^{th} cluster.

5) Recalculate the distance between each data point and the new obtained cluster centers. If no data point is reassigned then stop, otherwise repeat from step 3. This algorithm aims at minimizing an objective function, in this case, a squared error function.

$$J(V)=\sum_{i=1}^{k}\sum_{j=1}^{c_i}(\|x_i-v_j\|)^2 \ , \qquad (1)$$

c_i is the number of data points in i_{th} cluster, and k is the number of cluster centers.

C. Fuzzy Logic System

Owing to low computational requirement and capability of modeling human perception, fuzzy Logic (FL) is an efficient and flexible method for managing degrees of uncertainty in attack detection. Problems can be described in natural descriptions, linguistic terms, rather than the numerical values. The FL system consists of (i) fuzzifier that takes input values and determines the degree to which they belong to each of the fuzzy sets via membership functions (MFs); (ii) fuzzy inference system that defines a non-linear mapping of the input data vector into a scalar output, using fuzzy rules and (3) defuzzifier that maps output fuzzy sets into a crisp number [34]. A fuzzy set [35] is defined as [2]:

$$D=\{(x,\mu_D(x))\,|\,x\in X,\mu_D(x)\in[0,1]\}, \qquad (2)$$

where X represents the universal set, x is an element of X, D is a fuzzy subset in X and $\mu_D(x)$ is the membership function of fuzzy set D. A membership function is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1 [35].

Next we will fuzzify the input (features of SQLI) and the output (probability of injection), i.e. input and output are mapped into a set of fuzzy partitions. Here, a seven-input single-output fuzzy system is used, which is given by $f:U\subset R^m\to Z\subset R^n$, where $U=U_1\times....\times U_7$ is the input space and Z is the output space. Three fuzzy variables including 'low', 'medium' and 'high' (L, M, H) are used to describe the features. Their respective MFs (μ_A) [36] are triangular function calculated as:

$$f(x;a,c)=\max(\min(\frac{x-a}{b-a},\frac{c-x}{c-b}),0) \ , \qquad (3)$$

where a, b and c are the outputs of the k-mean clustering that represent lower, center and upper limits of a cluster respectively. To achieve overlap between the membership functions (overlapped fuzzy-sets) of each feature, the system makes an intersection with 15% -20% between the consecutive MFs.

Once the system acquires the fuzzy descriptions of the features distance, the Mamdani rule base (fuzzy reasoning) can be built to make an inference of detection of SQLI. Fuzzy reasoning, which is formulated by the group of fuzzy IF–THEN rules, presents a degree of presence or absence of association or interaction between the elements of two or more sets. In the proposed system, reasoning is carried out through the following rules:

- If more than half input variables are '*H*', the output variable is set to '*H*'.
- If both f_7 and f_2 are '*H*', the output variable is set to '*H*'.
- If both f_7 and f_1 are '*H*', the output variable is set to '*H*'.
- If both f_1 and f_2 are '*H*', the output variable is set to '*H*'.
- If f_7, f_2 and f_1 are '*H*', the output variable is set to '*H*'.
- If any of f_7, f_2 and f_1 is '*H*', the output variable is set to '*M*'.
- If both f_1 and f_2 are 'M', the output variable is set to '*M*'.

Other rules are obtained using the Cartesian product method of the seven features; which is to consider all the combinations of antecedent linguistic values and generate a fuzzy rule for each combination. The output variable of each case depends on the nature of dataset. The rules altogether deal with the weight assignments impliedly in the same way that humans think. The fuzzy inference processes all of the cases in a parallel manner, which makes the decision more reasonable.

The output of the fuzzy system is the probability of SQLI (PSQLI) and it is also described by three fuzzy variables, including 'high', 'medium' and 'low' with triangular MFs. The outputs of fuzzy values are then defuzzified to generate a crisp value for the variable. The most popular defuzzification method is the centroid, which calculates and returns the center of gravity of the aggregated fuzzy set [36] and is given by

$$\theta=\frac{\sum_{r=1}^{s}\mu^{(r)}\theta^{(r)}}{\sum_{r=1}^{s}\mu^{(r)}} \ , \qquad (4)$$

where $\theta^{(r)}$ is the center of the suggested output at rule r, n is the number of rules and $\mu^{(r)}$ is the MF at rule r. The obtained crisp value is then mapped to its range (low, medium, high) to indicate the potential of SQLI attack.

D. Rule Induction using Genetic Algorithm

In general, a rule base can be constructed by human experts or by machine learning techniques from datasets. The machine learning approach is useful where it is desired to extract rules from the analysis that can be related to conceivable human behavior. The essential feature of a GA is that a population of proposed solutions (coded using a "chromosome") is modified using biologically inspired operators (especially crossover and mutation), and incorporating a random component, to explore a solution space [37]. Formally, let $P(g)$ and $S(g)$ be parents and offspring in generation g; the GA is working as follows:

TABLE I. GENETIC PARAMETERS

Parameter	***Value***	***Description***
Population type	Bit string	Input data type to the fitness function
The initial population	Randomly	Cartesian product of all features
Population size	200 -1458	Number of chromosomes in each generation
Number of generation	Satisfying criteria	The highest ranking solution's fitness is reaching
Gene length	2 bits for all features + 1 bit for feature7 + 2 bits for the output	Length of unsigned bit string for each variable
Chromosome length	15 bits	(2×6)+1+2
Probability of cross-over	0.5	Default, combine two parents to form children in the next generation
Probability of mutation	0.015	Default, apply random changes to individual parents to form children
Selection function	Tournament	A number Tour of individuals is chosen randomly from the population and the best individual from this group is selected as parent.
Fitness function	Maximize attack detection	The objective is to maximize detection ratio between parents and children.

```
Procedure (GA)
   BEGIN
        g ←0
          Initialize P(g)
          Evaluate P(g)
          While (not matching the ending conditions)
          Recombine P(g) to yield S(g)
          Evaluate S(g)
          Select P(g+1) from P(g) and S(g)
        g ← g +1
   END
```

In general, the methods that combine the genetic and fuzzy approaches for generation of knowledge bases (KBs) can be divided into two main groups: genetic tuning and genetic learning [13]. If there exists a KB, we apply a genetic tuning process for improving the FRBS performance while preserving the existing RB. That is, to adjust FRBS parameters for improving its performance, maintaining the same RB. The second possibility is to learn KB components (an adaptive inference engine can be included). That is, to involve the learning of KB components among other FRBS components. Our system employs the genetic learning to learn the flexible inference engine.

The first step in applying GAs to the problem of rule learning is to map the initial rules (initial RB) into a suitable representation for genetic operations. The system that has been used is Michigan GA [13]. In Michigan GA, the population consists of multiple individuals, each individual codifies single rule, and the whole rule set is provided by combining several individuals in a population. For this problem, the variables (genes) are the linguistic values of each feature (low, medium, high). Many trials of different values of GA parameters were performed. Finally, the best-evaluated values of parameters were chosen as mentioned in Table I. The codification scheme and the fitness calculation are described below.

1) Chromosome Codification

The pre-selection of candidate rules (initial RB) used here allows each rule to be uniquely identified. The identification induces a simple binary codification of each rule in each chromosome and, consequently, the use of simple processes to create and handle the chromosomes. Fig. 2 illustrates a chromosome with 15 bits, represented in binary system, where each consecutive two bits from the position 1 to position 12 indicate a feature f_i (i=1 to 6) with "00" for low, "01" for medium and "11" for high linguistic term; whereas the bit at position 13 identifies a feature f_7 with values "0" to non-existing and "1" for existing and finally the last two bits represents PSQLI with "00" for low, "01" for medium and "11" for high linguistic term.

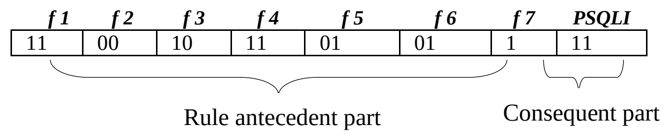

Fig. 2. Example of codification of rules

2) Fitness Function

In order to use genetic algorithms as the search procedure, it is necessary to define a fitness function which properly assesses the rules. The fitness function must be able to discriminate between the legal and illegal classification of queries. Finding an appropriate function is not a trivial task, due to the variations associated with the SQLI types. In general, the quality of rules in an FRBS is one of the parameters that favor accuracy, while the number of rules is the parameter that favors transparency, an FRBS with a small number of rules can make the model easily understood by the user. Several approaches in the field of FRBS reduce the FRB size at the expense of accuracy [38]. In this work, the primary objective is to enhance the accuracy; therefore, the numbers of rules are left as they are.

In this work, the method suggested by the authors in [39] is refined to improve the evaluation step performed by the GA in order to optimize the rules in the final FRB during the search process. The fitness value is calculated using the Correct Classification Rate (CCR) represented by each chromosome.

$$\text{Fitness} = \text{CCR} = \frac{\alpha}{A} - \frac{\beta}{B}, \tag{5}$$

where A is the total number of attack records, B is the total number of normal records, α is a total number of attack records correctly identified as attack and β is the total number of normal records incorrectly classified as attack (False positive).

IV. EXPERIMENTAL RESULTS

To evaluate the performance of the proposed system, a desktop application that integrates Java and MATLAB has been implemented. The dataset is downloaded from testbed [40] which is used to evaluate Amnesia approach in [3]. The test bed has two sets of inputs: "legit" set, which consists of legitimate inputs for the application, and "attack" set, which consists of attempted SQLIAs. All types of attacks were represented in this set except for multi-phase attacks. The multi-phase attacks include inference attacks and illegal/logically incorrect queries, such attacks require human intervention and interpretation. The testbed includes seven folders, three of them are used for training and the rest for testing. The result is analyzed using: (1) True negative (*TN*), which means the label of the SQL statement is normal and the classifier has classified it as normal. (2) True positive (*TP*) means that the classified label is the same as the true label which is abnormal. (3) False negative (*FN*) means that the classifier has made a classification mistake concerning the abnormal SQL statements. (4) False positive (*FP*), which means that a normal statement is misclassified to be an abnormal statement [9]. The tests are conducted according to Table I, and the fuzzy parameters are set as membership function type is triangular with 20% overlap.

The first experiment was conducted on the three different training sets to investigate the performance of the proposed system under both original Cartesian rules and enhanced version. The original Cartesian rules were the initial rules of the GA formed by all combinations of the seven features that have been previously mentioned in Section 3. Whereas the enhanced version contains the Cartesian version plus seven rules that contain only three features (f_1, f_2, and f_7), which have the higher impact on SQLI detection. Each other individual rule in the original Cartesian set contains all the seven features together.

TABLE II. RESULTS OF SQLI DETECTION OF TRAINING SET

Training Folder's subject	*No. of attacks URLS*	*No. of legit URLS*	*Original Cartesian Rules (1458 rules)*		*Enhanced Cartesian rules (1465 rules)*	
			TP%	*FP%*	*TP%*	*FP%*
Bookstore	3033	608	76.5	0	95.8	0.5
Checkers	3442	1359	67.3	0	96.8	1.2
Classifieds	3346	576	69.8	0	95.0	0

TABLE III. RESULTS OF SQLI DETECTION OF TESTING SET

Testing Folder's subject	*No. of attacks URLS*	*No. of legit URLS*	*Original Cartesian Rules (1458 rules)*		*Enhanced Cartesian rules (1465 rules)*	
			TP%	*FP%*	*TP%*	*FP%*
Events	3002	900	89.7	0	100	1.5
Employee	3497	660	89.9	0	100	0.6
Office Talk	3612	424	72.6	0	94.2	1.1
Portal	2968	1080	90.8	0	100	2.6

TABLE IV. RESULTS OF SQLI DETECTION OF TESTING SET (TOTAL OF 13079 ATTACKS, 3016 LEGIT URLS OF THE FOUR TESTING FOLDERS)

Type of population	*Population size*	*Membership function of 20% intersection*		*Membership function of 15% intersection*	
		TP%	FP%	TP%	FP%
Random	200	79.7	0	76.5	0
Random	600	81.8	0	77.6	0
Random	1000	82.6	0	80.3	0
Original Cartesian	1458	84.5	0	82.8	0
Enhanced Cartesian	1465	98.38	1.6	98	1.7

Table II indicates that the system can achieve high accuracy using the enhanced Cartesian rule with 96.8% *TP* for the attack set and 1.2% *FP* for the legit set of the Checkers dataset. The enhanced Cartesian rules improve the detection accuracy of attacks with a slightly increased false positive rate for the legit set. One reason for this increase is the fact that using the enhanced version activates some rules concerned with f1 which exists with high frequency in normal URLs. For example, the frequency of a character like '=' can be high in normal URLs.

When compared to the results in Table III, the enhanced Cartesian rules achieve higher accuracy in detection of SQLI in the three folders of the testing set with average increase of 3% *TP* and average decrease of 1% *TN*. One explanation of such result is that there are some attack URLs like "Password='&ret_page=""&querystring='" resulted after preprocessing stage in the training set. Such URLs do not consider most of SQLI features; thus they are not matched with any rule resulting in false negative (wrong classification). Regarding the Office Talk testing set, it has been noticed that the obtained results have the same range as the results of the training set due to the similarity of the URLs structure.

From the obtained results in table IV, it is confirmed that the proposed system provides good accuracy on the subject of increasing population size (number of initial rules). In general, increasing the population size leads to increasing the diversity of chromosomes. This diversity results in new offspring's in each generation that gives rise to increasing accuracy. However, increasing the number of rules increases the overhead. Furthermore, the experiments reveal that the system's accuracy can be improved as the level of fuzzification increases inside the membership function (intersection area). In the case of increasing the intersection by 5%, the accuracy changed by 2-4%. One explanation for this result is that the system's ability to deal with uncertainty is directly proportional with increasing the fuzzification level. Increasing the intersection level between membership functions for each feature will increase the ability of the fuzzy logic system to infer the result from the activated rules through fuzzy logic operation (min, and max).

TABLE V. COMPARATIVE STUDY

Methods	*Correct Responses*
The proposed system	98.4%
Neural Network system [28]	96.8%

In the last experiment, the accuracy (correct responses) of the proposed system that employs genetic fuzzy algorithm to detect SQLI and the comparative algorithm suggested by N. Sheykhkanloo [28] is given in Table V. The comparative system utilizes an effective pattern recognition Neural Network (NN) model for detection and classification of the SQLI attacks. From the illustrated results, our system outperforms the other one by 1.5%. In general, the correct responses of the neural network system depend mainly on the number of hidden layers that is commonly determined by the user. On contrast, the accuracy of our system depends on the number of utilized features and consequently the constructed rules, which characterize the flexibility factor for our system. Furthermore, the initialization parameters of GA can affect the performance of our system. These parameters are configured in the learning phase (offline processing), which consumes more time. In the testing phase (online processing), the computation time for detection is reasonable and acceptable. The duration is about 217 sec for 13079 attacks, i.e. 16.6 *ms* for one attack.

V. CONCLUSION

In this article, we proposed a genetic- fuzzy rule-based classification system for the SQLI attack detection. In the proposed system, the SQL statement is treated as a feature vector that characterizes the SQLI attack keywords. The genetic algorithm is adapted for FRBCS to improve the quality of matching implemented by each rule by means of adjusting FRBS parameters to increase the generalization power of the classifier. The quality of the proposed system depends mainly on the selection of the attributes used to build the feature vector. It has the potential to give a higher accuracy when comparing to other solutions that use SQL keywords separately for the problem of SQL injection. For new patterns that the proposed system cannot recognize, the system can be retrained so that it can detect the new patterns without a significant increase in processing time. The solution can be used in combination with positive logic based filtering as in the prototype implementation. We have presented the evaluation methodology and reported the results that prove that: (i) The proposed method outperforms other state-of-the art NN method. (ii) Enhanced Cartesian of GA population type improves detection results. Future work includes investigating more features to enhance the performance of the detection, and the ability to automatically reduce the number of rules in the rule base to improve the detection.

REFERENCES

[1] OWASP. (1 November, 2015). O.W.A.S.P. Top 10 Vulnerabilities. Available: https://www.owasp.org/index.php/Top_10_2013-Top_10.

[2] A. Moosa, "Artificial neural network based web application firewall for SQL injection," World Academy of Science, Engineering & Technology, vol. 64, no. 4, pp. 12-21, April 2010.

[3] W. G. Halfond and A. Orso, "AMNESIA: analysis and monitoring for neutralizing SQL-injection attacks, " Proceedings of the 20th IEEE/ACM International Conference on Automated Software Engineering, pp. 174-183, 2005.

[4] W. Y. Win and H. H. Htun, "Detection of SQL Injection Attacks by Combining Static Analysis and Runtime Validation," International Conference on Advances in Engineering and Technology, pp. 95-99, Singapore, March 2014.

[5] V. Nithya, R. Regan, and J. Vijayaraghavan, "A survey on SQL injection attacks, their detection and prevention techniques," International Journal of Engineering and Computer Science, vol. 2, issue 4, pp. 886-905, 2013.

[6] A. Tajpour, S. Ibrahim, and M. Masrom, "SQL injection detection and prevention techniques," International Journal of Advancements in Computing Technology, vol. 3, no. 7, pp. 82-91, 2011.

[7] S. Rohilla and P. K. Mittal, "Database security by preventing SQL injection attacks in stored procedures," International Journal of Advanced Research in Computer Science and Software Engineering, vol. 3, no. 11, pp. 915-919, 2013.

[8] R. Komiya, I. Paik, and M. Hisada, "Classification of malicious web code by machine learning," 3rd International Conference on Awareness Science and Technology, pp. 406-411, China, Sept. 2011.

[9] X.-R. Wu and P. P. Chan, "SQL injection attacks detection in adversarial environments by K-centers," International Conference on Machine Learning and Cybernetics, pp. 406-410, China, 2012.

[10] J. G. Carbonell, R. S. Michalski, and T. M. Mitchell, "An overview of machine learning," in Machine learning, ed: Springer, pp. 3-23, 1983

[11] B. Hammer and T. Villmann, "How to process uncertainty in machine learning?," European Symposium on Artificial Neural Networks, pp. 79-90, Belgium, 2007.

[12] L. S. Riza, C. Bergmeir, F. Herrera and J. M. Benítez, "Frbs: fuzzy rule-based systems for classification and regression in R," Journal of Statistical Software, vol. 65, no. 1, pp. 1-30, 2015.

[13] F. Herrera, "Genetic fuzzy systems: taxonomy, current research trends and prospects," Evolutionary Intelligence, vol. 1, no. 1, pp. 27-46, 2008.

[14] A. Sadeghian, M. Zamani and S. Ibrahim, "SQL injection is still alive: a study on SQL injection signature evasion techniques," International Conference on Informatics and Creative Multimedia, pp. 265-268, Malaysia, 2013.

[15] G. Wassermann and Z. Su, "An analysis framework for security in Web applications," Proceedings of the FSE Workshop on Specification and Verification of component-Based Systems, pp. 70-78, 2004

[16] G. Buehrer, B. W. Weide and P. A. Sivilotti, "Using parse tree validation to prevent SQL injection attacks," ACM Proceedings of the 5th International Workshop on Software Engineering and Middleware, pp. 106-113, 2005.

[17] S. Bandhakavi, P. Bisht, P. Madhusudan, and V. Venkatakrishnan, "CANDID: preventing sql injection attacks using dynamic candidate evaluations," Proceedings of the 14th ACM Conference on Computer and Communications Security, pp. 12-24, 2007.

[18] S. Ali, A. Rauf, and H. Javed, "Sqlipa: An authentication mechanism against sql injection," European Journal of Scientific Research, vol. 38, no. 4, pp. 604-611, 2009.

[19] Y. Huang, S. Huang, T. Lin, and C. Tsai, "Web application security assessment by fault injection and behavior monitoring," Proceedings of the 12th international conference on World Wide Web, pp. 148-159, Hungary, 2003.

[20] L. K. Shar and H. B. K. Tan, "Defeating SQL injection", Computer, vol. 46, no. 3, pp. 69-77, March 2013.

[21] A. Tajpour and M. JorJor Zade Shooshtari, "Evaluation of SQL injection detection and prevention techniques," Second IEEE International Conference on Computational Intelligence, Communication Systems and Networks, pp. 216-221, UK, 2010.

[22] R. Dharam and S. G. Shiva, "Runtime monitors to detect and prevent union query based SQL injection attacks," Tenth International Conference on Information Technology: New Generations, pp. 357-362, USA, 2013.

[23] F. Valeur, D. Mutz and G. Vigna, "A learning-based approach to the detection of SQL attacks," Proceedings of the Conference on Detection of Intrusions and Malware, and Vulnerability Assessment, pp. 123-140, Austria, 2005.

[24] E. H. Cheon, Z. Huang, and Y. S. Lee, "Preventing SQL injection attack based on machine learning," International Journal of Advancements in Computing Technology, vol. 5, issue 9, pp. 967-974, 2013.

[25] M. Kaushik and G. Ojha, "SQL injection attack detection and prevention methods: a critical review," International Journal of Innovative Research in Science, Engineering and Technology, vol. 3, issue 4, pp. 11370-11377, April 2014.

[26] M. Choraś, R. Kozik, D. Puchalski, and W. Hołubowicz, "Correlation approach for sql injection attacks detection," Advances in Intelligent Systems and Computing, Springer, vol. 189, pp. 177-185, 2013.

[27] N. M. Sheykhkanloo, "Employing neural networks for the detection of sql injection attack," Proceedings of the 7th International Conference on Security of Information and Networks, pp. 318-323, UK, 2014.

[28] N. M. Sheykhkanloo, "SQL-IDS: evaluation of SQLi attack detection and classification based on machine learning techniques," Proceedings of the 8th International Conference on Security of Information and Networks, pp. 258-266, USA, 2015.

[29] J. Skaruz, J. P. Nowacki, A. Drabik, F. Seredynski and P. Bouvry, "Soft computing techniques for intrusion detection of SQL-based attacks," Lecture Notes in Computer Science,Springer, Vol. 5990, pp. 33-42, 2010.

[30] J. Chen, L. Yang, H. Zhang, and Y. Liu, "A GA-based approach for SQL-injection detection", Future Information Engineering, vol. 49, p. 291, 2014.

[31] A. Adriansyah and S. H. M. Amin, "Knowledge base tuning using genetic algorithm for fuzzy behavior-based autonomous mobile robot," Proceeding of 9th International Conference on Mechatronics Technology, pp. 120-125, Malaysia, 2005.

[32] T. Kanungo, D. M. Mount, N. S. Netanyahu, C. D. Piatko, R. Silverman, and A. Y. Wu, "An efficient k-means clustering algorithm: analysis and implementation," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 24, no. 7, pp. 881-892, 2002.

[33] E. Forgey, "Cluster analysis of multivariate data: Efficiency vs. interpretability of classification", Biometrics, vol. 21, no. 3, pp. 768-769, 1965.

[34] S. M. Saad, "Application of fuzzy logic and genetic algorithm in biometric text-independent writer identification", IET Information Security, vol. 5, no.1, pp. 1-9, 2011.

[35] I. Elamvazuthi, P. Vasant, and J. F. Webb, "The application of mamdani fuzzy model for auto zoom function of a digital camera", arXiv preprint arXiv:1001.2279, 2010.

[36] M. Abdulghafour, "Image segmentation using fuzzy logic and genetic algorithms," Journal of WSCG, vol. 11,no. 1, pp.1-8, 2003.

[37] J. Ricketts, "Tuning a modified Mamdani fuzzy rulebase system with a genetic algorithm for travel decisions," 18th World IMACS / MODSIM Congress, Australia, pp. 768-774, 2009.

[38] M. E. Cintra and H. D. A. Camargo, "Fuzzy rules generation using genetic algorithms with self-adaptive selection," IEEE International Conference on Information Reuse and Integration, pp. 261-266, USA, 2007.

[39] R. B. Jadhav and M. B. B. Gite, "Real time intrusion detection with fuzzy, genetic and apriori algorithm," International Journal of Advance Foundation and Research in Computer (IJAFRC), Vol. 1, Issue 11, pp. 34-40, 2014

[40] Willian Halfond, 'Testbed', [Online]. Available: http://www-bcf.usc.edu/~halfond/testbed.html. [Accessed: 16- JUNE- 2016]

Compressed Sensing of Multi-Channel EEG Signals: Quantitative and Qualitative Evaluation with Speller Paradigm

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***Abstract*—In this paper the possibility of the electroencephalogram (EEG) compressed sensing based on specific dictionaries is presented. Several types of projection matrices (matrices with random i.i.d. elements sampled from the Gaussian or Bernoulli distributions, and matrices optimized for the particular dictionary used in reconstruction by means of appropriate algorithms) have been compared. The results are discussed from the reconstruction error point of view and from the classification rates of the spelling paradigm.**

***Keywords*—Compressed sensed; EEG; Brain computer interface; P300; Speller Paradigm**

I. Introduction

In recent years, compressed sensing (CS) has attracted considerable attention in areas like applied mathematics, computer science, and electrical engineering by showing that, in certain conditions, it is possible to surpass the traditional limits of sampling theory. CS builds upon the fundamental fact that many signals can be represented using only a few non-zero coefficients in a suitable basis or dictionary. Nonlinear optimization can then be used to recover such signals from very few measurements [1].The concept of compressed sensing is an example of practical use of new mathematical results. The difficulties for using in applications of such results are related to the way such concepts are understood, in a more or less intuitive manner, in order to facilitate the fusion between theory and applications.

The literature of recent years shows an impressive number of papers in the CS field, covering both 1D and 2D medical signals. Among the 1D signals the most frequently used in CS applications are the electrocardiogram (ECG) and electroencephalogram (EEG) since they are most used in the medical world as well. In the case of EEG signals, there is often a need of records for longer periods of time (i.e., during the night) or for a large number of channels.

A brain computer interface (BCI) is a communication system that does not depend on the normal exit ways towards peripheral nerves and muscles. The development of a BCI or a system based on the communication by means of the electroencephalographic signals (EEG) is capable to connect directly the human brain with the computer. Using the EEG signal as a communication vector between human and machine is one of the new challenges in signal theory. The main element of such a communication system is known as “Brain computer interface - BCI”. The purpose of the BCI is to translate the human intentions – represented as suitable signals – into control signals for an output device, e.g. a computer or a neuro-prosthesis. A BCI must not depend on normal output traces of peripheral nerves and muscles. In the last two decades many studies have been carried out to evaluate the possibilities of using the recorded signals from the scalp (or from the brain) for a new technology than does not imply the control of the muscles [2] [3].

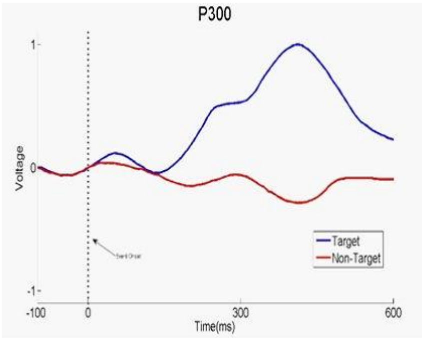
The BCI that uses the EEG signal is capable of measuring the human brain activity, detecting and discriminating certain specific features of the brain. The recent advances in BCI research widened the possibilities of applicability domains.

In this paper, we propose a compression method for EEG signals based on CS using universal EEG specific mega-dictionaries. In order to validate the proposed method, there were used the EEG recordings from the competition for Spelling, BCI Competition III Challenge 2005 - Dataset II. In order to rate the reconstructed signal, both quantitative and qualitative types of evaluation were used. As qualitative evaluation, we used the classification rate for the watched character based on P300 detection in the case of the spelling paradigm applied on the reconstructed EEG signals and using the winning scripts (Alain Rakotomamonjy [4]). For quantitative evaluation, there were used distortion measures such as PRD (percent of root-mean-square difference) and PRDN (namely PRD normalized) between the reconstructed and original signals.

II. Brain Computer Interface - P300 Speller Paradigm

P300 speller paradigm uses the P300 waves that are expressions of event related potential produced during decision making process. P300 has two subcomponents (as shown in Fig.1 a): the novelty P3 (also named P3a), and the classic P300 (renamed as P3b). P3a is a wave with positive amplitude and peak latency between 250 and 280 ms; the maximum values of the amplitude are recorded for the frontal/central electrodes. P3b has also positive amplitude with a peak around 300 ms; higher values are recorded usually on the parietal areas of the brain. Depending on the task, the latency of the peak could be between 250 and at least 500 ms.

One of the first examples for BCI is the algorithm proposed by Farwell and Donchin [5] that relies on the unconscious decision making processes expressed via P300 in order to drive a computer.



a) P300 Wave

b) P300 paradigm

Fig. 1. P300 wave and the classical P300 spelling paradigm described by Farwell-Donchin 1988

The P300 speller paradigm was described in [5]. The subject should watch a 6x6 matrix containing all letters and digits (as shown in Fig.1 b) and should focus the attention on characters from a given word. The protocol contains several stages:

Step 1: the matrix is presented to the subject for 2.5 seconds;

Step 2: all lines and all columns are highlighted randomly and alternatively each for 100ms.

The procedure consists in repeating step 2 for 15 times (15 epochs) for each char-acter, followed by a pause of 2.5 seconds (step 1). For each given character, there will be 6x2x15=180 intensifications: 2x15 will contain the target character (once when the column is highlighted, second for the line it belongs to, repeated for 15 epochs) and the rest will not contain it.

For the BCI III competition the dataset has been recorded from two different subjects in five sessions each and signals have been bandpass filtered in the range 0.1 - 60Hz and digitized at 240Hz. Each session is composed of runs, and for each run, a subject is asked to spell a word. For a given acquisition session, all EEG signals of a 64-channel scalp have been continuously collected. The train set contained 85 characters and the test set 100 characters for each of the two subjects. A more detailed description of the dataset can be found in the BCI competition paper [6].

The competition winners, Alain Rakotomamonjy and Vincent Guigue propose a method that copes with such variability through an ensemble of classifiers approach [4]. Each classifier is composed of a linear Support Vector Machine trained on a small part of the available data and for which a channel selection procedure has been performed. They succeeded a classification rate of 95.5% for 15 sequences and 73.5% for 5 sequences [4].

III. Compressed Sensing

In case of a vector $x \in \Re^n$ which can be represented using only few elements from the basis defined by the columns of the matrix $B \in \Re^{nxn}$, the x vector can also be written as:

$$x = B\gamma$$

where γ is the sparse decomposition of x in B.

The approach of compressed sensing assumes to take only a set of m measurements of x which can be obtained by projecting x on m random vectors with $m < n$. By considering these vectors as the lines of a matrix $P \in \Re^{mxn}$, the acquisition operation is described by the equation:

$$y = Px = PB\gamma = A\gamma \, .$$

The product $A = PB$ is also called effective dictionary and with this notation the known form of CS is expressed as:

$$y = A\gamma \, .$$

This equation shows how the sparse vector γ is acquired by means of matrix A . The name "compressed sensed" indicates that the number of projection vectors m is much smaller than the signal dimension n .

The key problem of CS is the recovery of the sparse n-dimensional vector γ from the $m << n$ projections contained by y . The system of equations is undetermined, but the number k of nonzero elements of γ is small under the sparsity hypothesis $k < m << n$. From γ , the original signal x can be obtained using the equation $x = B\gamma$.

CS uses the property of the signal that it is sparse in a certain basis. A fundamental result published in [7], [8] is: if γ has enough entries with value zero and matrix A fulfills certain conditions, then γ is the sparsest solution of the acquisition system of equations. Namely, γ can be obtained as a solution of the following optimization problem with constrains:

$$\hat{\gamma} = \arg\min_{\gamma} \|\gamma\|_p \quad \textit{subject to} \quad y = A\gamma$$

For the most common values of p , $p = 0$ and $p = 1$, this becomes:

$$\hat{\gamma} = \arg\min_{\gamma} \|\gamma\|_0 \quad \textit{subject to} \quad y = A\gamma$$

or: $$\hat{\gamma} = \arg\min_{\gamma} \|\gamma\|_1 \quad \textit{subject to} \quad y = A\gamma$$

The first case, where the l_0 norm is used, is an NP-hard problem [9] and this requires an algorithm of non-polynomial complexity for solving it; NP-hard problems are practically impossible to be solved for usual dimension of data. The second case that uses the l_1 norm is known as Basis Pursuit [10]. BP is a convex optimization problem that can be reformulated as a linear programing problem for which there are available many efficient algorithms.

IV. Method

The key element in the success of signal compression based on compressed sensing is the right choice of the dictionary based on which the reconstruction will be done. Generally, the ECG and EEG biomedical signals don't have a very high sparsity in standard dictionaries. Due to their specificity, in the case of ECG signals the alignments of waveforms from which the dictionary atoms are selected with respect to the R wave or QRS complex improve very much the results. For EEG signals, alignments are difficult or even impossible since they do not usually contain repetitive elements in the time domain. Thus, the EEG signals might be discussed in the frequency domain as well.

In the case of the BCI spelling experiment, a temporal change in the waveforms, the P300, has been observed after about 300ms after the stimulus. This temporal behavior has been clearly put into evidence by averaging several EEG signals with the natural alignment represented at the moment when the stimulus was applied. This temporal alignment based on the start time of the stimulus and tacking into account that P300 appears after about 300 milisec does not allow a real time compressed acquisition. For this alignment, preprocessing is needed for both the acquisition and the decompression of the signal. The introduction of preprocessing at acquisition has as a major drawback the elimination of the advantage of the compressed sensed technique, namely, very low complexity of calculations in the acquisition stage.

Starting from the above statements, we tested the possibility to build a universal mega-dictionary consisting of EEG segments from all 64 channels. Thus, there were selected for each channel three atoms, consisting in EEG segments from the corresponding channel, so in total one obtained a dictionary made up of 3x64 = 192 atoms. The size of the dictionary is 192x240, because each atom has the size of 240. For the construction of the dictionary, the training signal from the paradigm of spelling was used. The testing of the method was done using EEG test signals which consist in compressed sensed EEG signals [11].

As acquisition matrix, we tested three types of matrix:

- Bernoulli matrix with elements -1, 0 and 1
- Random matrix
- optimized matrix depending on dictionary [12] - (product of random matrices and the dictionary transposed)

Compared with [11] where it was made an analysis of the dictionaries used in the reconstruction phase in this work is intended to analyze the projection matrix used in the compression stage.

V. Experimental Results and Discussions

For the evaluation of the analyzed methods we used the dataset II of the BCI Competition III 2005 -P300 Spelling.

For compression evaluation we used the compression rate (CR) defined as the ratio between the number of bits needed to represent the original and the compressed signal.

$$CR = \frac{b_{orig}}{b_{comp}}$$

To validate the compression we evaluated the distortion between the original and the reconstructed signals by means of the PRD and PRDN (the normalized percent-age root-mean-square difference):

$$PRD\% = 100\sqrt{\sum_{n=1}^{N}(x(n)-\tilde{x}(n))^2 \Big/ \sum_{n=1}^{N}(x(n))^2}$$

$$PRDN\% = 100\sqrt{\sum_{n=1}^{N}(x(n)-\tilde{x}(n))^2 \Big/ \sum_{n=1}^{N}(x(n)-\bar{x})^2}$$

where $x(n)$ and $\tilde{x}(n)$ are the samples of the original and the reconstructed signals respectively, is the mean value of the original signal, and N is the length of the window over which the PRDN is calculated.

For qualitative evaluation of the method based on the classification rate in spelling paradigm, we used scripts from the winners, A. Rakotomamonjy and V. Guigue [4] (the scripts implement classification based on all 64 EEG channels).

For the construction of the dictionary, we used the training EEG signals from subjects A and B, respectively, and for the testing of the proposed method we used the test EEG signal from subject B.

Next we will present the results of EEG signals decompression from subject B. The results will be presented both as a measure of distortion of the original and decompressed EEG as well as the classification rate in spelling paradigm.

Thus, Table 1 presents the classification results in paradigm spelling using original data and software from [4]. It shows an average classification using all channels of 89.37% and on most individual channels there is a classification rate of 93%.

TABLE I. CLASSIFICATION PERFORMANCE% IN P300 SPELLING FOR ORIGINAL DATA (FOR B SUBJECT) AND SOFT FROM [4]

P300 Spelling - classification performance %
Original data – uncompressed and classificated by A. Rakotomamonjy and V.Guigue
36 53 61 68 73 78 83 82 84 88 91 93 90 90 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 **Average Classification% = 89.37%**

Tables 2 - 4 presents the classification results for all 64 channels for a compression of 10:1, respectively 5:1 for subject B and Bernoulli matrix vs. random matrix vs. optimized matrix depending on dictionary.

TABLE II. CLASSIFICATION PERFORMANCE% IN P300 SPELLING FOR RECONSTRUCTED EEG SIGNAL WITH SOFTWARE FROM [4] FOR A COMPRESSION CR = 10:1 RESPECTIVELY CR = 5:1 SUBJECT B AND BERNOULLI MATRIX

P300 Spelling - classification performance % for subject B and Bernoulli matrix
CR = 10:1
24 34 48 55 55 62 63 66 73 76 79 81 83 83 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 87 **Average Classification% =81.75%** **PRD_mean = 53.6** **PRDN_mean =54.54**
CR = 5:1
33 45 58 63 70 75 80 80 88 86 88 94 91 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 92 **Average Classification% = 88.17%** **PRD_mean = 40.26** **PRDN_mean = 40.93**

TABLE III. CLASSIFICATION PERFORMANCE% IN P300 SPELLING FOR RECONSTRUCTED EEG SIGNAL WITH SOFTWARE FROM [4] FOR A COMPRESSION CR = 10:1 RESPECTIVELY CR = 5:1 SUBJECT B AND ACQUISITION MATRIX BY TYPE RANDOM

P300 Spelling - classification performance % for subject B and random matrix
CR = 10:1
26 33 44 52 57 62 59 67 76 80 80 80 82 85 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 86 **Average Classification% = 80.98 %** **PRD_mean = 53.63** **PRDN_mean = 54.57**
CR = 5:1
23 41 52 59 70 74 79 83 87 88 86 90 87 86 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 **Average Classification% = 86.01%** **PRD_mean = 39.74** **PRDN_mean = 40.38**

TABLE IV. CLASSIFICATION PERFORMANCE% IN P300 SPELLING FOR RECONSTRUCTED EEG SIGNAL WITH SOFTWARE FROM [4] FOR A COMPRESSION CR = 10:1 RESPECTIVELY CR = 5:1 SUBJECT B AND OPTIMIZED MATRIX DEPENDING ON DICTIONARY

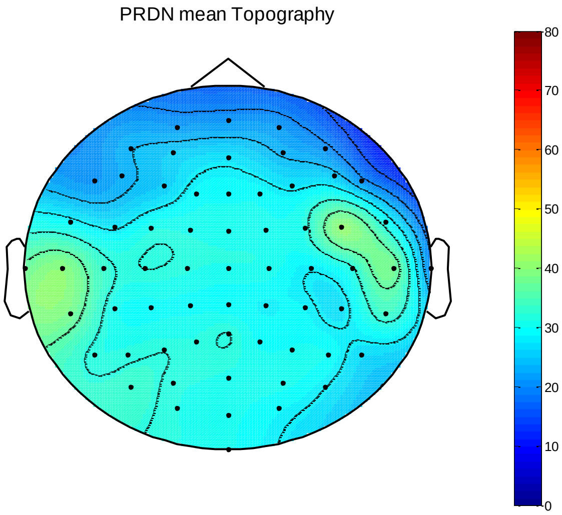
P300 Spelling - classification performance % for subject B and optimized matrix depending on dictionary
CR = 10:1
33 49 59 62 71 75 81 84 88 90 91 95 93 93 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 97 **Average Classification% =92.40%** **PRD_mean = 42.32** **PRDN_mean = 43.07**
CR = 5:1
34 48 58 66 74 79 82 83 86 90 89 90 90 91 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 94 **Average Classification% = 90%** **PRD_mean = 29.28** **PRDN_mean = 29.77**

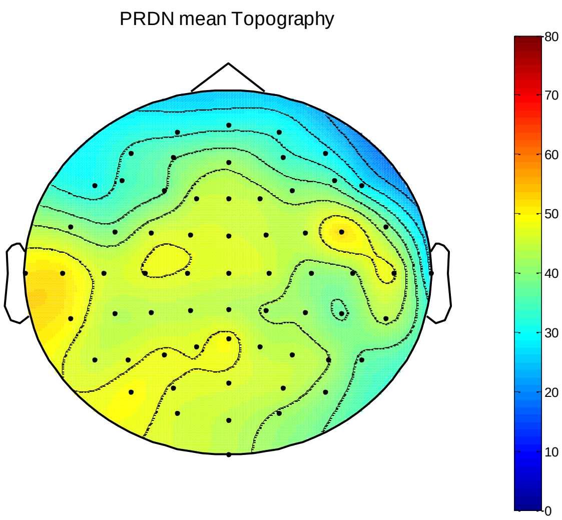
TABLE V. CLASSIFICATION PERFORMANCE% IN P300 SPELLING FOR RECONSTRUCTED EEG SIGNAL WITH SOFTWARE FROM [4] FOR A COMPRESSION CR = 12:1 AND OPTIMIZED MATRIX DEPENDING ON DICTIONARY VS. RANDOM MATRIX

P300 Spelling - classification performance % for subject B for CR = 12:1
CR = 12:1 optimized matrix depending on dictionary
33 46 53 61 66 70 76 79 83 84 87 87 88 87 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 **Average Classification% =86.71%** **PRD_mean = 46.28** **PRDN_mean =47.12**
CR = 12:1 random matrix
12 25 31 39 42 46 47 59 65 69 71 76 76 74 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 79 **Average Classification% = 73.15%** **PRD_mean = 58.81** **PRDN_mean = 59.84**

Results obtained with Bernoulli matrix are comparable to those achieved with random matrix. But when using optimized matrix depending on dictionary results are much improved, being comparable to results obtained with original signals. If we strictly reference to the classification rate in paradigm of spelling, classification rates are obtained even improved for CR = 10: 1 and 5: 1.

TABLE VI. THE TOPOGRAPHY OF PRDN FOR EEG COMPRESSED SENSING (CR = 5:1 AND RESPECTIVELY CR = 12:1 FROM UP TO DOWN)





VI. CONCLUSIONS

In this paper a comparative analysis of the results obtained using several types of projection matrices (matrices with random i.i.d. elements sampled from the Gaussian or Bernoulli distributions, and matrices optimized for the particular dictionary used in reconstruction by means of appropriate algorithm) and a mega-dictionary for EEG signals compressed sensing is presented. For the evaluation of the proposed method we used the dataset from the BCI Competition III 2005 - P300 Spelling. In order to evaluate the results of the EEG signal reconstruction the PRDN was used in parallel with the classification rate of the spelling paradigm assessed using the scripts from the winner of the competition (the version of classification using all 64 channels). The best results were obtained with matrices optimized for the particular dictionary used in reconstruction.

Thus, for the mega-dictionary the best results in terms of classification at the spelling paradigm are obtained for CR = 5:1 and 10:1 when the achieved classification rate was 90%, respectively, 92% (for the original signals the classification rate was 89.37%). In terms of error, the PRDN was 29.77 for the 5:1 compression and PRDN = 42.32 for the 10:1 case.

The results demonstrate that the proposed method with mega-dictionary and optimized matrix depending on dictionary provides greatly improved results compared to the standard matrices.

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REFERENCES

[1] M. A. Davenport, M. F. Duarte, Y. C. Eldar, and G. Kutyniok, "Introduction to Compressed Sensing," in Compressed Sensing: Theory and Applications, Cambridge University Press, 2012.

[2] Blankertz, B., BCI competition III webpage [Online]. Available: http://ida.first.fraunhofer.de/projects/bci/competition III

[3] Blankertz, B., Mueller, K.-R., Curio, G., Vaughan, T., Schalk, G., Wolpaw, J., Schloegl, A., Neuper, C., Pfurtscheller, G., Hinterberger, T., Schroeder, M., Birbaumer, N., The BCI competition 2003: Progress and perspectives in detection and discrimination of EEG single trials, IEEE Trans. Biomed. Eng, vol. 51, no. 6, pp. 1044–1051 (2004).

[4] A. Rakotomamonjy, V. Guigue, BCI Competition III: Dataset II-Ensemble of SVMs for BCI P300 Speller, IEEE Transactions on Biomedical Engineering,Vol:55, Issue: 3, pp. 1147 – 1154, 2008.

[5] Farwell L.A., Donchin, E. Talking off the top of your head: toward a mental prosthesis utilizing event-related brain potentials. Electroencephalography & Clinical Neurophysio.. 70(6):510-23, 1988

[6] Data Acquired Using BCI2000's P3 Speller Paradigm (http://www.bci2000.org)

[7] D. L. Donoho and M. Elad, "Optimally sparse representation in general (nonorthogonal) dictionaries via l1 minimization," Proceedings of the National Academy of Sciences, vol. 100, no. 5, pp. 2197–2202, 2003.

[8] D. Donoho, M. Elad, and V. Temlyakov, "Stable recovery of sparse overcomplete representations in the presence of noise," IEEE Transactions on Information Theory, vol. 52, no. 1, pp. 6–18, Jan. 2006.

[9] B. K. Natarajan, "Sparse approximate solutions to linear systems," SIAM J. Comput., vol. 24, no. 2, pp. 227–234, Apr. 1995.

[10] E. Candes and T. Tao, "Decoding by linear programming," IEEE Transactions on Information Theory, vol. 51, pp. 4203–4215, 2005.

[11] M. Fira, V. A. Maiorescu, L. Goras, "The Analysis of the Specific Dictionaries for Compressive Sensing of EEG Signals", Proceedings of the ACHI 2016, Venice, Italy, 2016

[12] Cleju N., Fira M., Barabasa C., Goras L., Robust reconstruction of compressively sensed ECG patterns, ISSCS 2011 (The 10-th International Symposium on Signals, Circuits and Systems), 30 June – 1 July 2011, Iasi, pp. 507-510, 2011

Multicast Routing Problem Using Tree-Based Cuckoo Optimization Algorithm

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***Abstract*—The problem of QoS multicast routing is to find a multicast tree with the least expense/cost which would meet the limitations such as band width, delay and loss rate. This is a NP-Complete problem. To solve the problem of multicast routing, the entire routes from the source node to every destination node are often recognized. Then the routes are integrated and changed into a single multicast tree. But they are slow and complicated methods. The present paper introduces a new tree-based optimization method to overcome such weaknesses. The recommended method directly optimizes the multicast tree. Therefore a tree-based typology including several spanning trees is created which combines the trees two by two. For this purpose, the Cuckoo Algorithm is used which is proved to be well converged and makes quick calculations. The simulation conducted on different types of network typologies proved that it is a practical and influential algorithm.**

Keywords—Multicast tree; routing; Cuckoo Algorithm; optimal function

I. Introduction

The rapid development of network and multi-media technologies caused the multimedia services in media such as conference video, distance learning and coordination affairs to be gradually changed into major proceeding of internet activities. The multicast is a really proper way for these services, since it possesses strict conditions of service quality such as band width, delay, delay fluctuation etc. Multicast is attributed to condition in which the sender wants to send his data packets to a group of network nodes or receivers who actually form a casting group. It is evident that the advantages of this task include less waste of bandwidth and network sources, parallelism in the network, reduced load of sender and network traffic. The subject of multicast routing based on service quality is an important issue for researches in network and a serious problem for future generation of networks with high efficiency and performance. Abundant methods have been used for this problem, so the purpose of multicast routing based on service quality is to find an optimized multicast routing tree, so that it would meet the limitations of service quality such as band width, delay and delay fluctuations by minimizing the access expenses. The establishment of a multicast tree could solve the problems of multicast routing. One of the most important issues to implement the multicast services is the type of designing multicast tree in a way that better quality and efficiency of multicasting tree is regarded. As previously mentioned, finding a tree with such limitations is a NP-Complete problem [1]. There are two ways to solve the NP-Complete problem: 1- An optimal solution at final time 2- a close optimal solution using a heuristic algorithm [2]. Numerous methods have been presented for the problem of tree-based multicast routing which tried to improve the efficiency of tree-based multicast routing process using the designed tree [3] [4]. The meta-heuristics methods recommend acceptable solutions at proper time to solve the NP-hard problems in the era of engineering and sciences. Cuckoo Optimization Algorithm is one of the latest and most effective ways for evolutionary optimization which have further ability to identify the global optimal points. The Cuckoo Optimization Algorithm is a meta-heuristic optimization method which is effective for solving the problems of continuous nonlinear optimization. This algorithm simulates the behavior of cuckoo in nesting and egg dropping to solve the problems of optimization [5]. The present paper aims to design an efficient multicasting tree by taking the advantage of capabilities of Cuckoo Optimization Algorithm.

II. Related Works

For multicast routing we need a multicast tree by which the multicast packet could be delivered to destination. The limitation of node battery is one of the points which should be regarded in multicast routing of mobile ad hoc networks. Routing should be able to increase the network lifetime. Finding a multicast tree which meets the routing limitations such as battery energy, band width and end-to-end delay is a NP-Complete problem. Therefore acquisition of a multicast tree is not possible in polynomial time. The smarts methods are required to solve such problems [6] [7] [8]. Different algorithms have been presented for multicast routing in ad hoc networks. A group of these algorithms are developed from the unicast algorithms. In such algorithms no limitation is usually considered. Another group of multicast algorithms in ad hoc networks include the algorithms which apply the smart algorithms to search for multicast tress which meet the limitations of the problem. The Genetic and Ant Colony Algorithms are amongst the smart algorithms [9] [10].

The Genetic Algorithm is an evolutionary algorithm in which the chromosomes are combined with each other in every generation till the new chromosome is produced. In Genetic Algorithm every chromosome is a solution for one problem. The Genetic Algorithm is based on a biology theory which indicates that the superior parent could survive to produce the next generation and the weak parents are convicted to death. The Ant Colony Algorithm is an instance of decentralized search techniques. In this algorithm, the agent search activities is based on the ant behavior in nature. The mechanism applied for transmission of data between agents (ants) about the route and route selection time is the ability to spread pheromones on the path. When the ants move, they spread an amount of pheromone on ground and mark the route in this way. When a new ant wants to move, it selects the route with the highest probability to be selected. It is the route on which the pheromone is spread. The ants traverse the same route while it also adds certain amount of pheromone on the route. Therefore, the probability of selecting the route is gradually augmented by increased amounts of pheromone speared on the route. For multicast routing in ad hoc networks which could meet the limitations of problem, certain algorithms were presented profited from the Ant Colony Algorithm and Genetic Algorithm. They are amongst the smart algorithms which could be used for solving the NP-Complete problems. The noteworthy point is that they are not capable to discover the solution all the time. They may not reach the answer or find the semi-optimal solution. One of the other smart algorithms which could be used for multicast routing in ad hoc networks is Flock Algorithm. The Genetic Flock algorithms was developed based on the behavior of flocks. The Flock Algorithm was made from several components. Each component is the solution for one problem. Every component searches the problem space and advances to the solution using the best personal space as well as the best place achieved by population. The main advantages of Flock Algorithm could be cited as follows: simple concept, easy implementation, high power to control the parameters, high search power, high computation efficiency compared to mathematical algorithms and creative techniques [11][12]. Many researchers discussed the application of Particle Swarm Optimization Algorithm (PSO) to solve the problem of routing with QoS limitations. The PSO Algorithm was recommended to solve the problem of QoS multicast routing which could obtain a practical multicast tree using the switching routes. This algorithm could be converged by lower computational cost for optimal or close optimal solution. This chapter represents several studies conducted on tree-based multicast routing.

III. TREE-BASED MULTICAST ROUTING

The rapid development of network and multimedia networks caused the multimedia services in networks such as conference video, distance learning and cooperating affairs to be gradually transformed in to the main proceedings of online activities. The multicast activities are proper for this purpose since it possess the strict conditions of service quality (QoS) such as band width, delay, delay fluctuation etc. Therefore, rapid implementation of multicast routing with high quality is an important research issue. Multicast is referred to a condition in which the sender wants to send his data packets to a group of network nodes or receivers which actually form a multicasting group. It is evident that the advantages to this task include less waste of band width and network resources, network parallelization, reduced load of sender and reduced network traffic. So, multicast routing based on services quality (QMR) seeks to find a multicast routing tree which is able to meet the limitations of service quality such as band width, delay and delay fluctuations by minimizing the access expense. Establishment of a multicast tree could solve the problems of multicast routing. There are commonly three kinds of multicast trees: source-based tree, Steiner tree and center-based tree. The Steiner and source-based trees are the two common types of shortest route. The Steiner tree is usually applied in real multimedia communications. The problem of The Steiner tree is to find a tree with the least expense which includes a number of specific nodes named terminal. It is amongst the NP-Complete problems. The problem of Steiner tree has different types. In one type of Steiner tree, several points are presented on a two-dimensional paper as input and the purpose is to produce a tree on Euclidean plane which bears the least expense and encompasses all points. This problem is also introduced in perpendicular form in which the tree lines should be designed only vertically or horizontally. This issue has abundant applications in physical circuit design. Another type of Steiner tree is used in graph which is used in following sections. In this problem, a weighted graph G= (V, E) and a subset of vertices in the graph (T϶V) named terminals are presented. The purpose is to find a GT (V, E) tree (a tree encompasses the set of terminals). The non-terminal nodes are generally used to reduce the tree expenses. They are called Steiner points. The problem of Steiner tree has many applications such as one-to-several routing in computer systems, transportation systems, relief police, post stations etc. An instance of Steiner tree in a graph is shown in Figure (1). In this figure, the terminal nodes are drawn in red color and the edges of Steiner tree are in bold type.

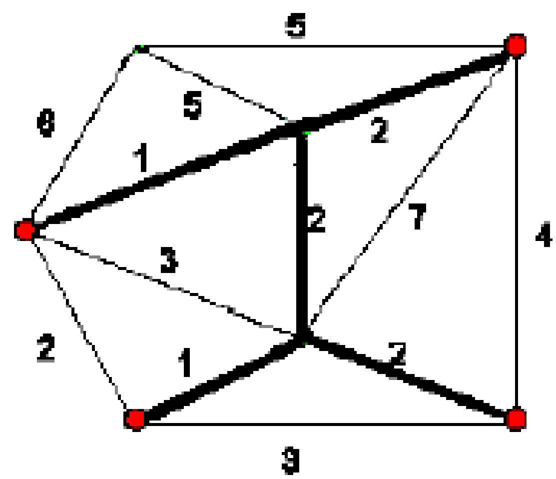

Fig. 1. Steiner Tree in Graph

One of the important issues at the time of implementing the multicast services is the type of designing a tree-based multicast algorithm in a way that quality and efficiency of multicast tree is considered. As mentioned before, the discovery of a tree with such limitations is a NP -Complete problem. There are mainly two solutions for Complete-NP problems:

1) An optimal solution at final time

2) A close-optimal solution by a heuristic algorithm

The first solution is an optimal way but the NP-HARD situation of problems makes it impractical. On the other hand, the second method is a possible way. Several heuristic ways have been presented to solve the multicast routing problems with limitations of service quality which is described as follows.

IV. Cuckoo Optimization Algorithm

Optimization is defined as discovering a method to implement a work in the best possible method. Optimization is basically changing a series of primary information and using the problem data to reach a proper solution. The Cuckoo Optimization Algorithm is a meta-heuristic optimization algorithm which is efficient for solving the continuous nonlinear optimization problems. The following figure demonstrates the flowchart of Cuckoo Optimization Algorithm (COA). Similar to other evolutionary algorithms, the COA also initiates with a primary population. The population encompasses the cuckoos. Several cuckoos have eggs which lay them in the nests of the host cuckoos. Some of these eggs which are similar to the eggs of host bird have higher opportunity for growth and changing to an adult cuckoo. Other eggs are recognized by host bird and destroyed. The amount of grown up eggs signifies the appropriateness of the nests existing in the area. The higher numbers of eggs live and survive in the area shows the higher level of profit (tendency) in that area. Therefore, the situation in which more eggs are survived will be a parameter for COA optimization.

V. Algorithm Recommended for Multicast Routing

Heuristic and non-heuristic algorithms have been recommended for multicast routing. Several of these algorithms aimed to minimize the expenses. The expense function in majority of these algorithms was equal to degree of efficiency from network sources. Therefore, maximizing the efficiency of network sources as an engineering target was regarded in addition to route establishment. Many other methods also considered criteria such as band width, end-to-end delay etc. and presented proper algorithms. There is still the need for algorithms which are able to present an acceptable response during acceptable time, in other words they should possess well scalability. The recommended model firstly selects the optimal tree through suitable routes between source and destination. In this method, the number of existing routes between source and destination is firstly recognized. Then the upper and lower limits are applied for routes. The upper and lower limits are regarded for each series of algorithm implementation. In lower limit, the 1 value is for each route and upper limit is the number of existing routes. Based on these upper and lower limits between source and destination, the Cuckoo Algorithm is applied. Subsequent to application of Cuckoo Algorithm, the optimal route and tree are selected. Figure (2) demonstrates the flowchart of recommended method.

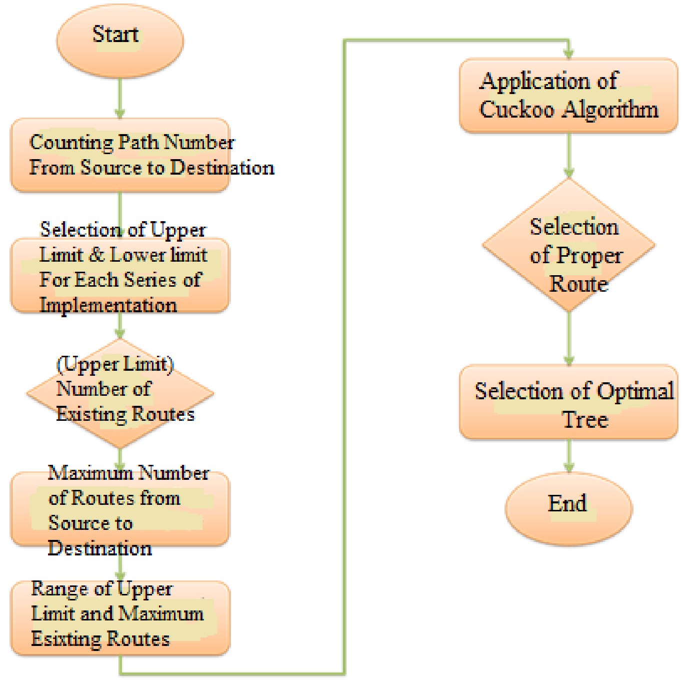

Fig. 2. Flowchart of Recommended Method

A. *Description and Formulation of Problem*

The communication networks are usually demonstrated as G=<V, E> undirected graph in which V is the set of all nodes (routers or switches) and E is the set of all edges which signifies the physical or logical relation between nodes. On each edge of $e \in E$ in G, three weights of $B(e): E \to R^+$ ، $D(e): E \to R^+$ ،$C(e): E \to R^+$ are located which are positive real numbers and respectively show the parameters of expense, delay and accessible band width. A T (s,M) multicast tree is an acyclic sub graph from G graph which covers the $s \in V$ source node and a set of $M \subseteq V - \{s\}$ destination nodes. M= $|M|$ also indicates the number of destination nodes in multicast tree. Besides, the T(s,M) could encompass other nodes existing in a multicast tree, but they are not part of a multicast group and are recognized as Steiner points. The Pt (s,d) signifies an exclusive route in T tree which connects a source node to an s destination node. The expenses and service quality parameters are defined as follows:

Expense: The expense of multicast tree T (s,M) is total expenses of all tree edges which is calculated as follows:

$$C\big(T(s,d)\big) = \sum_{e \in E_T} C(e) \tag{1}$$

Delay: The general delay of each route is total delay on edges in Pt(s,d) route which is calculated as follows:

$$D(Pt(s,d) = \sum_{e \in Pt(s,d)} D(e) \tag{2}$$

Band width: the accessible band width on Pt(s,d) is the minimum band width existing on each edge of route Pt(s,d) which is calculated as follows:

$$B\big(Pt(s,d)\big) = min_{e \in Pt(s,d)} B(e) \tag{3}$$

If Δ_d is limitation of delay and β_d is limitation of band width of d destination node, the problem is to find a T(s,M) multicast tree so that it includes s source and all $d \in M$ destinations and meet the following conditions:

$$Cost(T) = \min\Big(\sum_{(a,b)\in Et} C(a,b)\Big)$$

$$D\big(Pt(s,d)\big) \le \Delta_{d,}, \qquad \forall d \in M$$

$$B\big(Pt(s,d)\big) \le \beta_{d,}, \qquad \forall d \in M \tag{4}$$

B. Construction of Multicast Tree

The network typology is conducted based on depth-first search algorithm. We have to determine the routes from source to destination. The algorithm uses a stack instead of row to determine the traverse route. We need to construct a multicast tree which covers the source and all members of group for multicast routing. The construction of a multicast tree through selection and combination of different routing paths is a complicated process. There are three types of reasons: firstly, the multiple routes may be found in the same members of group. Secondly, the results of possible loops are resulted from the combination of routing paths. The new routes after the omission of loop may split in QoS needs of user. Thirdly, the different sequences of routing paths resulted from the omission of possible loops may be added to multicast tree which covers different multicast tress. So, when the size of a multicast group exceeds a certain threshold, a huge degree is regarded from possible compounds. We use a multicast tree which is able to render the best possible value to evaluate the multicast tree with Evt criterion. The evaluation criterion of multicast tree is regarded from several parameters and agents such as QoS satisfaction degree, price and cost. This problem is a Steiner Minimum Tree problem which is a SMT and minimum expense of multicast tree. This is a certain kind of combined optimization which has been proved as a NP-Complete.

C. Definition of Fitness Function

The multicast routing algorithm should form a new multicast tree in the least possible time. Then the algorithm speed to find a multicast tree is a proper scale to compare two multicast routing algorithms in ad hoc networks. The multicast possesses a communication network to receive a simple message from a practical program and deliver a copy of message to several receivers in different locations. One of these challenges is minimization of network sources applied in multicast system. A new fitness function is used as an index and scale to compare the multicast trees.

$$r = \alpha \times \mathrm{cost}(T_i) + \beta \times delay(T_i) \tag{5}$$

Next tree $\longleftarrow T_i = T_i + \beta(r_i)(T_j - T_j)$

$$T_{ji} - T_{i1} = \left(T_{j1} - T_{i1}, T_{j2} - T_{i1}, \cdots, T_{jn} - T_{in}\right)$$

$$T_{jn} - T_{in} = \begin{cases} round\left(T_{jn} - T_{in}\right) & T_{jn} > T_{in} \\ 1 & T_{jn} \le T_{in} \end{cases}$$

$\beta(r) = \beta_0 e^{-\gamma r^m}$ Waste

D. Determining the Number of Routes in Network Typology

Firstly several trees are created randomly which include the related sender and receivers. This tree forms the primary population. Each tree is named as exclusive tree. Then the fitness of each tree is made by calculating the fitness function. In the recommended algorithm, we look for the optimal tree which is selected on the basis of the routes created by application of Cuckoo Algorithm. Using Search Algorithm, depth-first search of all available routes from source to destination is specified. Also, the number of routes from source to destination must be specified for each group. It should be implemented for entire groups. In a one-dimensional habitat, number of paths is shown to all destinations. Three groups are demonstrated in Figure 3. For each group, there are routes from source to destination which are shown in a habitat.

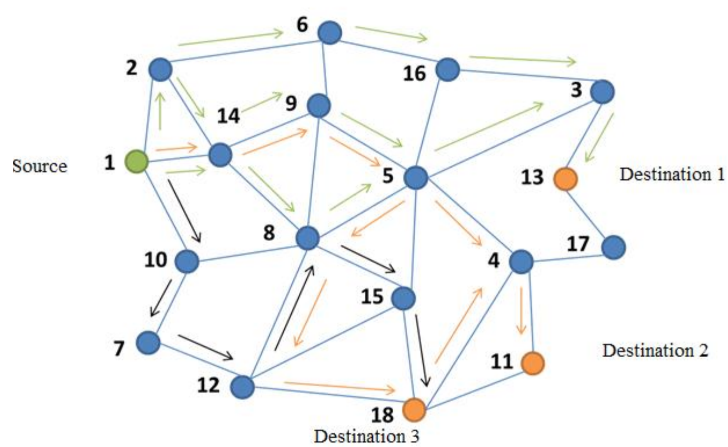

Fig. 3. Number of Specified Routes from Source to Destination

$$\begin{array}{cc} & \begin{array}{ccc} 1 & 2 & 3 \end{array} \\ \text{Route} = & \left[\begin{array}{ccc} 3 & 2 & 1 \end{array}\right] \end{array}$$

As the figure suggests, the routes have been specified for all destinations. There are three routes from source to destination 1. Besides, there are 2 routes from source to destination 2 and 1 route from source to destination 3.

E. Solving the Multicast Tree Using Firefly Algorithm

After creating the topology and determining the number of routes from source to destination, we apply the Cuckoo algorithm in specified routes. We should select the optimal routes with regard to Cuckoo Algorithm. The optimal tree is created by these routes. To solve an optimization problem, it is necessary to form the values of variables in the form of a habitat. In Cuckoo Optimization Algorithm, this array is called "habitat". In an optimization problem, the next N_{var} of a habitat will be a1xN_{var} habitat which shows the present status of cuckoo living. The habitat is defined as follows:

$$Habitat = [x1, x2, \ldots, x_{Nvar}] \quad (6)$$

The fitness level (profitability) in present habitat is obtained by evaluating the profit function (f_p) in habitat, so:

$$Profit = f_p(habitat) = f_p(x1, x2, \ldots, x_{Nvar}) \quad (7)$$

As seen, the COA is an algorithm which maximizes the profit function. To apply the COA to solve the minimization problems, it is sufficient to multiply the minus sign by cost function. To start the optimization algorithm, a habitat matrix in $N_{pop}*N_{var}$ is produced. Certain random number of eggs is allocated for each of these habitats. The cuckoo lays 5 to 20 eggs in nature. This number is used as upper and lower limits for allocating the eggs to each cuckoo in different replications. Another habit of a cuckoos is that it lays eggs in a certain range. The maximum range of laying egg is called Egg Radius Radius (ELR). In an optimization problem, the upper limit of var_{hi} variable and upper limit of var_{low} variable belong to each Cuckoo with ELR which is proportional to total number of eggs, number of present eggs as well as the upper and lower variables of problem. So, the ELR is defined as follows:

$$ELR = \alpha \times \frac{Number\ of\ current\ cuckoo's eggs}{Total\ number\ of\ eggs} \times (var_{hi} - var_{low}) \quad (8)$$

The Alfa is a variable which is used to adjust the maximum value of ELR.

In recommended method, the matrices are lower limit and maximum number of routes from source to destination in each group. The matrices of random number of eggs are regarded with regard to Cuckoo Algorithm. Each route with less egg waste will be selected as the best route with least waste. In proposed method, the least number of eggs in a route with less waste will be selected as respective route.

VI. Results and Evaluation of Recommended Method

The efficiency of proposed algorithm compared to other algorithms was studied in this section. The Mat lab Software is used for simulation. All simulation experiments were conducted on 4GM RAM ،CPU 460 2.4GHz Core i5 system. The multicast nodes were selected randomly. The source and destination nodes and weight of multicast tree habitat were created randomly. The Firefly Algorithm is used to comparison. Therefore, the fitness function parameters, expense and delay were used to compare two methods in simulation. The possible trees are formed by DFS algorithm. A tree is randomly selected. The nodes existing in the tree forms the primary population. Therefore, the nodes of multicast group were randomly selected in this graph which is 30% of the total nodes in the graph. The source and destination nodes and the weight of edges of multicast tree is randomly created. The Firefly Algorithm is applied for comparison. Figure (4) and (5) show the implementation of multicast tree based on recommended method and Firefly Algorithm. The nodes are randomly created in both figures with similar typology. Followed by the application of Cuckoo and Firefly algorithms, the multicast tree is shown. The 5 node and 15, 20 and 24 nodes are respectively regarded as destination nodes. As shown in recommended algorithms and Firefly algorithm, there is difference only in one route. The other routes are the same in source and destination.

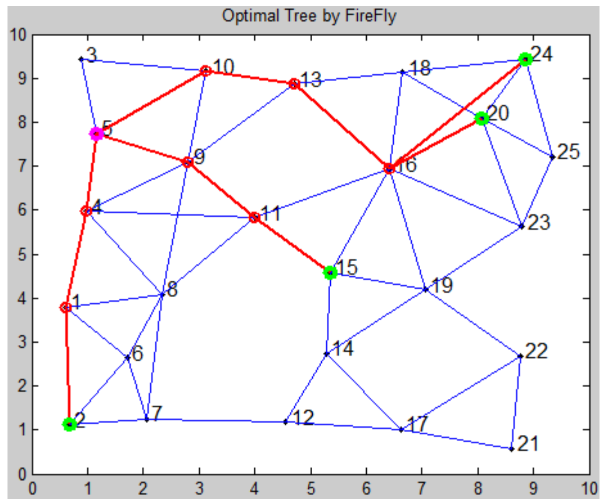

Fig. 4. Optimization of Tree by Firefly Algorithm

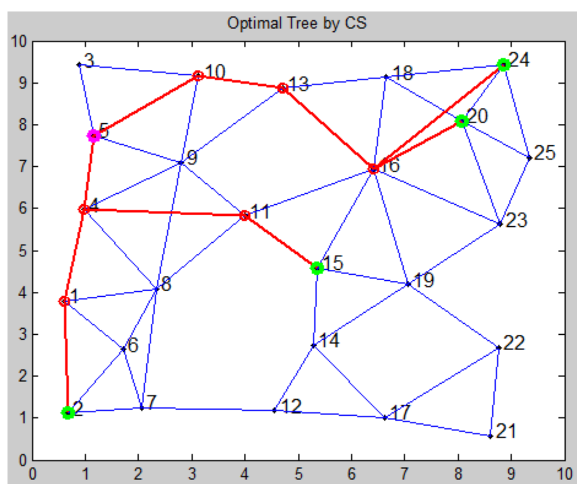

Fig. 5. Optimization of Tree by Cuckoo Algorithm

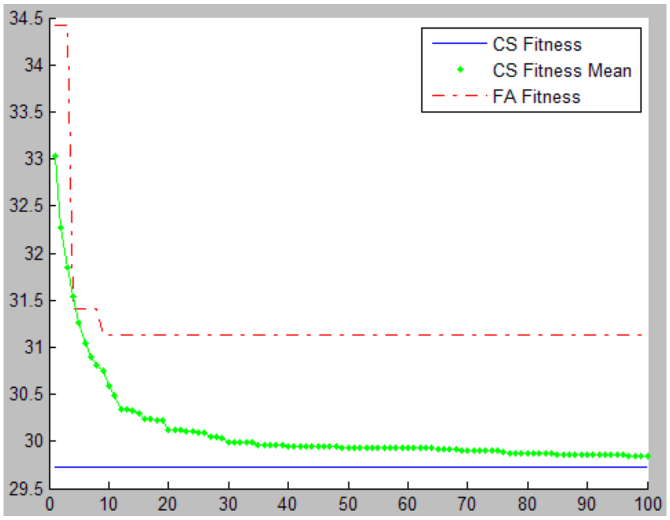

Fig. 6. Values of Fitness Function for Recommended Algorithm

The results of simulation showed that the recommended methods could efficiently and effectively perform the multicast routing based on service quality. Figure (6) shows the values of fitness function for recommended algorithm and Firefly Algorithm. The recommended algorithm for convergence is faster than Firefly algorithm. As shown in Figure, the value of fitness function in recommended algorithm reduces with increased production of generation. The increased value of fitness function makes the multicast tree more desirable. When the generation grows, the function value tends to be stable; this process shows that the algorithm could be effectively converged.

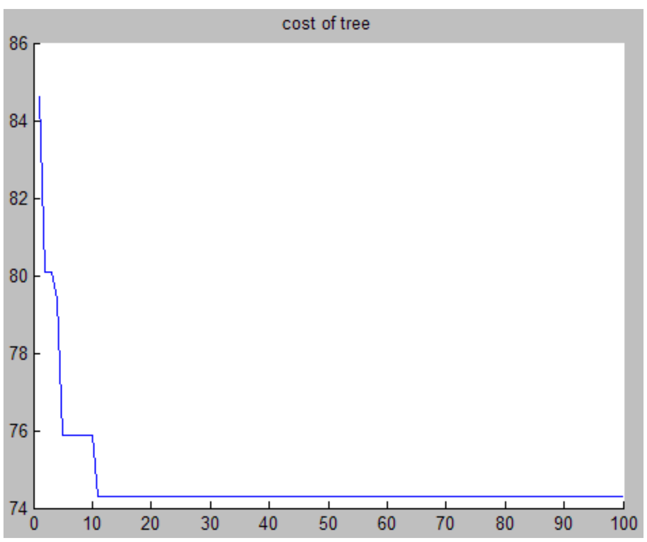

Fig. 7. Expense of Multicast Tree in Recommended Method

Figure7 shows the expense of Cuckoo tree. As shown, the recommended algorithm rendered fewer expenses. Besides, the algorithm could find the optimal solution more quickly. Although the expense curve of this algorithm has more fluctuations at the beginning, its stable value is less at the end. It is observed that the recommended method could conduct the routing of service quality. The solution of routing problem along with the service quality of Steiner tree is a new suggestion. The papers conducted in routing by Steiner tree only regarded one criterion, but we focused on criteria of delay and expense in this algorithm. The recommended algorithm for networks in large size response within a shorter time compared to other algorithms. The expense of their tree is also proper and acceptable.

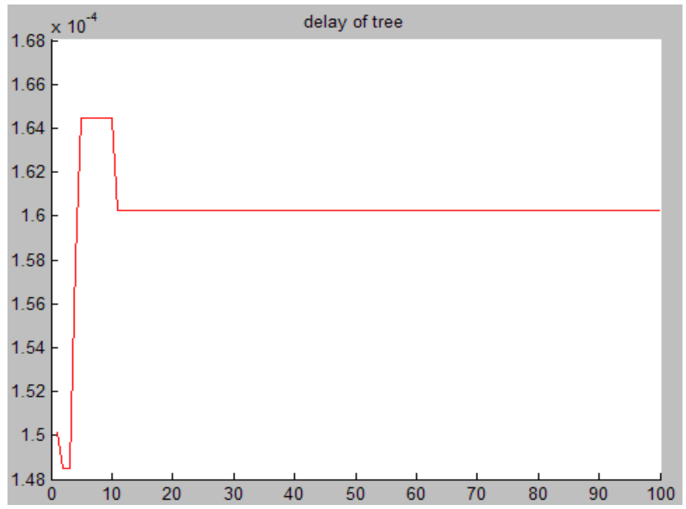

Fig. 8. Recommended Algorithm Delay

Figure 8 shows the delay of Cuckoo algorithm. Generally the tree expense of delay from an optimized tree is a more expensive solution than an optimized expense of multicast routing tree. Similarly, the tree delay of an optimized multicast routing tree is relatively higher than the solution of optimized delay tree. Therefore the negotiation between tree expense and tree delay should be required for an efficient/proper tree between tree delay and tree expense.

VII. Conclusion

This paper presents a new method for tree-based optimization method. The recommended method directly optimizes the multicast tree. So, a tree-based typology including several extending trees is created and combines the tress two by two. For this purpose, the Cuckoo Algorithm is used due to its appropriate convergence and fast calculations. The simulations conducted on different types of network typologies proved that it is a practical and effective algorithm. The results of simulation show that recommended algorithm is not trapped in local optimization point. Although the growth rate of its implementation increased with higher number of nodes in multicast group compared to Firefly algorithm, generally it possess more proper efficiency in terms of relative error percent, response quality and time to achieve the global optimal response. The results of optimization show that Cuckoo Algorithm shows more simplicity and ease of implementation. It is faster compared to Firefly Algorithm and its efficiency is less dependent on its parameters compared to other algorithms. We aim to solve the problem of multicast routing in terms of service quality parameters by other meta-heuristic algorithms and tree growth methods in future studies.

REFERENCES

[1] Wang, Z and Crowcroft, J. (1996). “Quality of service for supporting multimedia application”, IEEE Journal on Selected Areas in Communication 14, pp. 1228–1234.

[2] Charikar, M., Naor, J and Schieber, B. (2004). “Resource optimization in QoS multicast routing of real-time multimedia”, IEEE/ACM Transactions on Networking, pp. 340–348.

[3] Wang, X., Cheng, H and Huang, M. (2014). " QoS multicast routing protocol oriented to cognitive network using competitive coevolutionary algorithm", Expert Systems with Applications 41, PP. 4513–4528.

[4] Qu. R., Xu. Y and Juan. P. (2013). " Particle swarm optimization for the Steiner tree in graph and delay-constrained multicast routing problems", Springer Science+Business Media, LLC 2012, PP. 317–342.

[5] Rajabioun, R. (2011). " Cuckoo Optimization Algorithm", Applied Soft Computing 11, Elsevier, pp. 5508–5518.

[6] Hua, W., Hong, X., Shanwen Y., Zhao, S. (2011). "A tree-growth based ant colony algorithm for QoS multicast routing problem", Expert Systems with Applications 38,11787–11795.

[7] Vijayashree, H.P., Leena, Sh. (2015). " Modelling of Multicast Tree Problems using Binary Discrete Particle Swarm Optimization", International Journal of Computer Science and Mobile Computing, Vol.4 Issue.6, pp. 926-928.

[8] Rehab, F. Abdel-K. (2011). " An Improved Discrete PSO with GA Operators for Efficient QoS-Multicast Routing", International Journal of Hybrid Information Technology Vol. 4, No. 2.

[9] Younes, A.(2011). " An Ant Algorithm for Solving QoS Multicast Routing Problem", International Journal of Computer Science and Security (IJCSS), Volume (5), Issue (1), pp. 1630 – 1635.

[10] Lu, T and Zhu, J. (2013). " Genetic Algorithm for Energy-Efficient QoS Multicast Routing", IEEE COMMUNICATIONS LETTERS, VOL. 17, NO. 1, pp. 31 – 34.

[11] Rong, Q. Xu, Y. Juan P. Castro, D. (2013). " Particle swarm optimization for the Steiner tree in graph and delay-constrained multicast routing problems", Journal of Heuristics, Volume 19, Issue 2, pp 317-342.

[12] Shen, M., Zhan, Z.H., Chen, W.N. (2014). "Bi-Velocity Discrete Particle Swarm Optimization and Its Application to Multicast Routing Problem in Communication Networks", IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 61, NO. 12.

Cost-effective and Green Manufacturing Substrate Integrated Waveguide (SIW) BPF for Wireless Sensor Network Applications

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***Abstract*—This paper presents a comparison between innovative technique for implementation of substrate integrated waveguide band pass filter centered at 4 GHz and conventional PCB results . Two poles filter is designed, simulated and fabricated. The novel fabrication process technique is based on green manufacturing where physical etching of metal layer of aluminum is glued on paper substrate. The pass band filter is composed of two resonant adjacent and symmetric cavities separated by a coupling iris. The same topology is adopted with conventional substrate and PCB technology to validate the new technique results. The bandwidth achieved is almost four times wider than found with PCB technology developed for UWB applications. The proposed technique keeps the advantages of conventional SIW technology including low profile, compact size, complete shielding, easy fabrication, low cost for mass production as well as convenient integration with planar waveguide components including transitions. Moreover, the flexible quality of paper offer the possibility to fabricate conformal shapes of SIW components which is not possible with conventional rigid substrates made with PCB technology . In addition to the advantages of eco friendly, renewable, light weight , and ultra low cost materials.**

Keywords—Substrate Integrated Waveguide; Band pass filter; Wireless sensor network; green material technology; paper substrate

I. Introduction

During the last two decades, the main issue for microwave and millimeter researchers is to decrease the pollution impact of electronic devices and integrated circuits made with chemical etching process as the conventional PCB and LTCC technologies. Indeed, The major part of these concerns is devoted to develop new green electronic technologies based on eco-friendly materials and ecological process of fabrication. Thus employing new class of microwave clean components. This aim will be achieved during manufacturing, operational life and even after disposal.

In order to satisfy the Industrial and Consumers requirements in microwave devices, tests are multiplied to validate the feasibility of new process of fabrication including materials. In fact, Internet of things and the new generation of wireless sensor networks applications require a large number of sensor node. Thus, using a low cost materials and easy to manufacture process is a necessity.

The proposed manufacturing technique involves physical etching of aluminum foils to design metal shape using milling machine. Chemical etching is avoided together with the use of acids and other high-polluting solutions. Hence, this process can be considered as a solution to reduce the environmental impact in the future of electronic circuits fabrication and paves the way to develop and manufacture green electronic devices for wireless communication systems.

Furthermore, paper and aluminum are two materials very cheap, low weight and commercially available. In addition, these materials are completely recyclable.

Paper is already used in the literature in [1,2], where three layers of photographic paper are glued, then the metal layer is made by dropping the ink with silver nano particles using inkjet printer. This manufacturing process achieve high accuracy but it is so expensive due to the high cost of silver . In addition ,many layer of ink are required to achieve the right thickness of metal layer which becomes very time consuming .Other ecologic substrate used in last few years is textile for wearable applications, such as tracking position of fire fighting men [3].Also, Plastic was exploited for high frequency applications [4]. In [5], process of fabrication has complicated steps and demanding many tools such as UV light source, photo-lithographic etching with photo resist film deposed on the cooper surface and NaOH solution was used to remove the unimpressed film. Also, protective and sacrificial layer are required. Moreover, the adhesive layer seems a problem with milling machine because it becomes not solid after heating process .

These Investigations are applied for ambient monitoring of gas, temperature, humidity in library, museums and artworks, wall and buildings, hospitals and operating theaters, supply chain sensing and logistics of food industries, agriculture and farming maturation of fruit and vegetables , growth of plants, temperature of green houses. Especially, the light weight and ecologic properties adopted in this work make it suitable to be integrated in a sensor mounted directly on plants.

Moreover, this work covers the Substrate Integrated Waveguide technology. This solution, among different technologies, is particularly suitable for implementing microwave structures: it allows for planar integration of active and passive components as well as antennas, to realize systems on ship integrated circuits. Also, it exhibits low loss and complete shielding. Thus, preventing interference and cross-talk phenomena. In addition SIW technology is a mature technology; in fact it has shown incredible advances over the last decade, where a variety of components and systems have been proposed: selective filters, compact and broadband transmission lines, antenna arrays, and active antennas, tunable devices have been designed and tested [10-15] . SIW structure is composed by two rows of metalized vias arranged with a calculated distance to avoid loss radiation even for high frequency and used to realize metal edge walls. Those vias are integrated in a dielectric filled waveguide and spaced width depends on the operation frequency as the traditional rectangular waveguide but in planar form [16-18]. It works in TE or TM modes, instead of the quasi-TEM mode of a microstrip line. Planar transitions such as coplanar waveguides (CPWs) and microstrip lines can be perfectly integrated to SIWs cavities [6-8] .

This paper will exploit the advantages of SIW technology mentioned above and depicts the green manufacturing process as well as the reliability of eco friendly material based paper substrate compared to PCB technology.

This paper is structured into four sections: section II shows the manufacturing process, section III displays the proposed prototypes of filter realized based Taconic TLX substrate then with novel technique based paper substrate and section IV concludes the paper.

II. Fabrication Process

The structure is mono-substrate employing single sheet of paper with a thickness of 0.5 mm which is similar thickness with respect to three layers of Kodak in [1,2]. In fact, air bubbles between the paper sheets are avoided and no more stick-glue is employed to attach three layer of paper, thus, decreasing losses in dielectric comparing to[1,2]. One can say that , this manufacturing process is more reliable than that used in [1,2].

Fig. 1. First step: gluing paper with Aluminum foils

The metallization of paper substrate is simply consisting in gluing both face with aluminum foil using a very thin layer of glue which has no effect on performance of the filter based paper substrate Fig. 1.

The well known aluminium foil of the kitchen as metal layer replacing adhesive cooper used in [5]. To design an SIW microwave component, electromagnetic paper characterization is mandatory. In fact, single sheet of paper with a thickness of 0.5 mm and a negligible roughness is composed by 50% of cellulose and 50% of cotton. The returned electric properties are dielectric permittivity of 2.25 and loss tangent of 0.045 based on a ring resonator over the UWB frequency band. The aluminum foil characterization is required to estimate the total losses of the structure .The aluminum conductivity was characterized at 2.45 GHz and its conductivity is comparable to the standard bulky aluminum [14]. This result shows that aluminum is more conductive than conductive ink for paper ink-jet printing technology used in [1] and the conductive fabrics employed for textile substrate in [4]. At the same time, the use of bi-component epoxy glue represents a very small percentage (in terms of weight) of non-ecological materials over the entire structure. In fact, after gluing paper and aluminum, a heating process is required to solidify the glue. This step is very important to realize the device on paper substrate with a computer numerical controlled (CNC) milling machine exactly as conventional PCB technology with SIW Taconic traditional substrate .Subsequently, arbitrary planar shapes are possible on paper substrates like standard one . The tool available spans from the 0.25 mm in diameter for the circuit edges to the 3 mm tool for etching wide areas of aluminum. In addition, the milling machine equipped with spiral drill tool can also drilled tens of via holes per minute required to manufacture SIW based components. Once the device is prototyped with the milling machine, the SIW via holes have to be metalized. In order to avoid the spread of the conductive paste within the paper caused by the porosity characteristic of paper, a developed solution is adopted after experimental tests: covering the inner wall of each post with thin layer of epoxy glue. Another fast heating process is required to solidify the coating. Then, after shielding the vias from the effect of spreading issue, a liquid conductive paste is employed on the inner wall of each via to ensure the best ohmic contact between top and bottom aluminum foils. The last heating process in a thermal oven is necessary to increase the conductivity of the conductive paste and therefore the electrical performance of the metallization. The process is simple and easy comparing to [5].

From this work and by means of this new manufacturing process, the costs and complexity of overall structure and systems on chip are significantly decreased [13,15].

III. Experimental Verification of the Filer Performance

A. SIW Band pass filter with conventional PCB

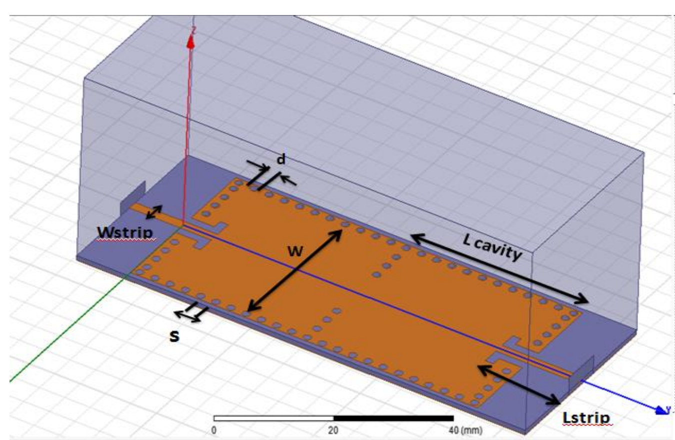


Fig. 2. Geometry of the SIW filter on TLX substrate (d=1.5mm, s=3mm, Lstrip=16.15mm, Wstrip=1.6 mm, a=11.5 mm, Lcavity=32.8 mm, w=33.7mm)

Two pole band pass filter is designed simulated and then fabricated. The electric properties of standard substrate Taconic TLX 9 are a relative dielectric permittivity equal to 2.5 and loss tangent of 0.0019. The height used for this prototype is equal to 0.76mm. The filter is designed to work on the UWB frequency band. The dimensions of the symmetrical cavities and the iris of coupling between them are optimized for the central operation frequency of 4GHz.

The top layer and geometry of the filter are presented in Fig. 2 while the bottom layer is a fully metalized ground plane.

For the sake of clarity, Fig.3 shows 3D view of the horizontal and vertical symmetry plane of the filter designed in this work. The simulations are carried out with ANSYS HFSS software.

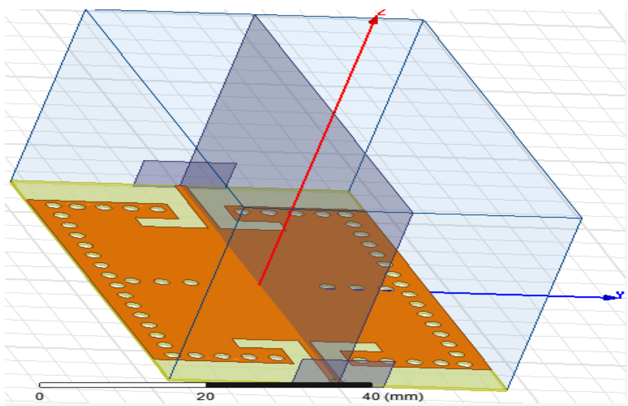


Fig. 3. 3 D topology of the proposed pass band filter with symmetrical plane in HFSS

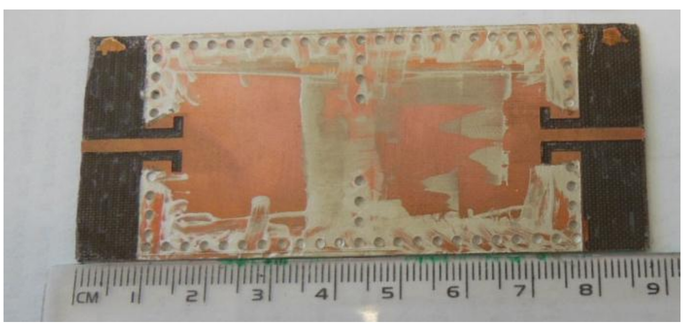


Fig. 4. Top view of fabricated TLX-based SIW filter

Fig. 4 shows the top face of the fabricated TLX substrate filter where vias are metalized with conductive paste .

The measured results are shown in Fig.5, where 230MHz of bandwidth achieved slightly wider with respect to simulation and an insertion loss of 2.27 dB is obtained at the frequency center 4 GHz compared to 0.89dB in simulation . The rejection out of band on both side of the transmission band is over 20dB, which guarantee a good selectivity and avoid interference with connected other planar microwave devices. In the same line , a good superposition in the transmission and reflexion coefficient is achieved between the measurement and simulations results. The bandwidth in measurements is slightly wider than simulation .This can be explained by the effect of soldering SMA port to transitions. While the matching is over 15dB for both measurements and simulations.

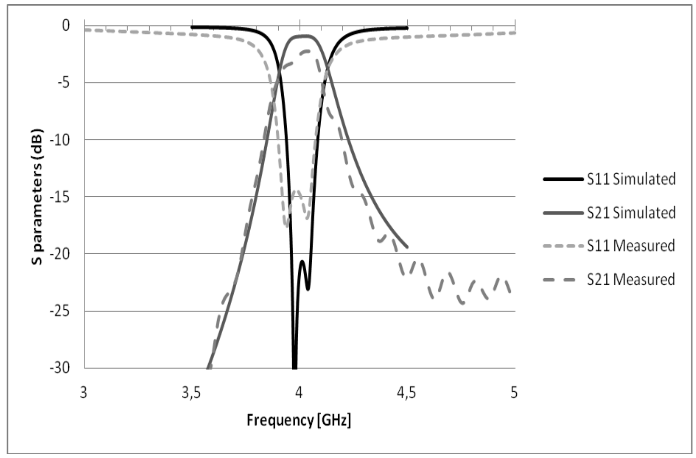


Fig. 5. Simulated and measured scattering parameters of the SIW filter on TLX 9 conventional substrate

B. SIW Band pass filter physical etching technique and paper substrate

The same design of the two cavities of the filter is employed as above. The dimensions are optimized for band-pass operation centered at 4 GHz. This prototype is designed to test the accuracy and the precision of the milling machine in the fabrication of devices based on paper substrate and aluminum metallization.

Transitions from the 50 Ohm feeding microstrip line to the filter are designed to achieve good performance in terms of matching and insertion loss [9]. The design and the dimensions of this component are displayed in Fig. 6.

Both top and bottom faces of the fabricated filter are shown in Fig. 7, where the bottom layer is a fully metalized ground plane. The photograph shows the precision and the accuracy of the proposed technique and machine in sharp corners of the transitions also with this kind of substrate.

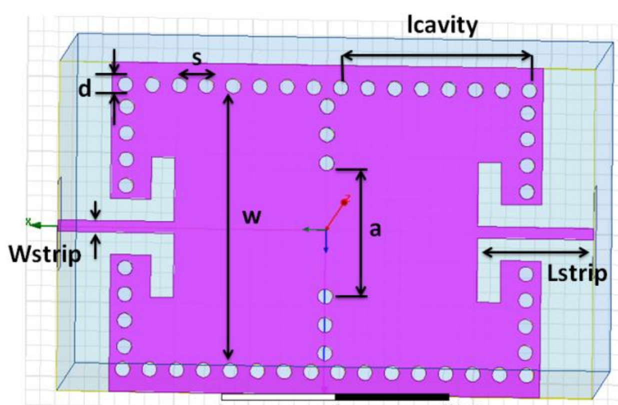
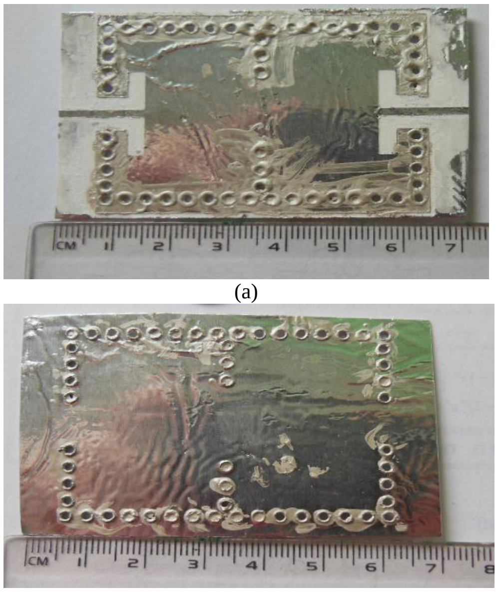


Fig. 6. Geometry of the SIW filter on paper (*Lstrip* =15.5 mm, Wstrip =1.52 mm, *a*=16.8 mm, *lcavity* = 26.8 mm, w=38 mm, *d*=2 mm, *s*=3.6 mm)



(a)

(b)

Fig. 7. Paper-based SIW filter (a) top face (b) bottom face

The simulated and measured frequency responses of the component are reported to Fig.8. An insertion loss of 5 dB at 4 GHz is obtained. The measured frequency response presents a shift in low frequency with respect to the simulated results. This discrepancy could be caused by small inaccuracies during the characterization of the electrical parameters of the paper substrate, which is a very critical step. In addition, the performance of the proposed filter may be affected by the non perfect metallization of the vias as discussed above.

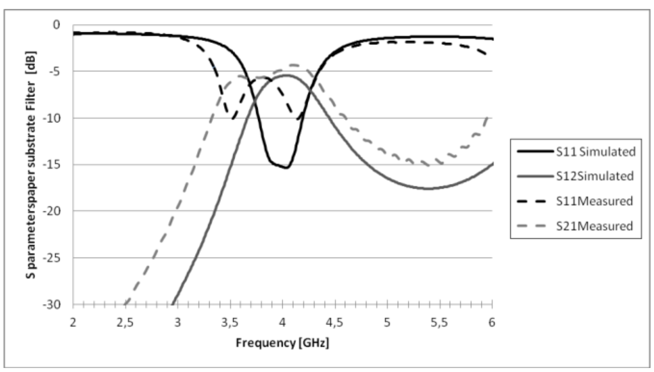


Fig. 8. Simulated and measured scattering parameters of the SIW filter on paper

As shown in Fig. 8 , the measured bandwidth 880 MHz achieved is four times wider than with the conventional Taconic substrate mentioned above. In fact, the resonance of the two cavities are merged to enlarge the bandwidth. The out of band rejection is over 15 dB in measurement on lower and upper side of the transmission band and validating the simulation results which maintain the target specifications in terms of minimum attenuation required to avoid interference. Moreover, the reflexion coefficient shows the two similar poles in the transmission band around the central frequency. A vector network analyzer (VNA) is employed to measure the frequency response of the prototyped filter.

There is an experimental difficulty to solder a standard SMA connector on aluminum transition for measurements . Therefore, the filter is measured with a universal test fixtures designed for the tests of paper components. In fact, it contains fixed and movable pin connectors to accommodate different length of substrate Fig. 9.

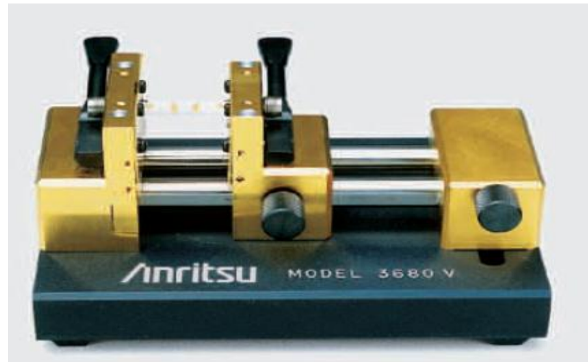


Fig. 9. Anritsu Universal test fixtures facilitating measurement of structures based paper

IV. Conclusion

This work highlights for the first time a comparison between standard substrate used with (PCB) technology and new physical etching technology . The development of green electronic fabrication components is attracting many researchers as well as industrial to avoid chemical impact on the environment. The bandwidth of filter based paper substrate is almost four time wider than conventional substrate TLX . Based on the results achieved in this paper, this implementation can be adopted for the realization of devices for the next conformal and wireless systems since it combines the advantage of low cost, flexible, eco-friendly materials and simple process of fabrication. Further studies and tests are in progress to improve the paper losses. In the same time, some steps in the manufacturing process are identified to pave the way for possible future works in Wireless sensor network and internet of things applications .

Acknowledgment

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References

[1] R. Moro, S. Kim, M. Bozzi, and M. Tentzeris, "Novel Inkjet-Printed Substrate Integrated Waveguide (SIW) Structures on Low-Cost Materials for Wearable Applications," 42th European Microwave Conference 2012 (EuMC 2012), Amsterdam, The Netherlands, Oct. 28–Nov. 2, 2012.

[2] G. Orecchini, V. Palazzari, A. Rida, F. Alimenti, M. M. Tentzeris, and L. Roselli, "Design and fabrication of ultra-low cost radio frequency identification antennas and tags exploiting paper substrates and inkjet printing technology," *IET Microw. Antennas Propag.*, vol. 5, no. 8, pp.993–1001, Jul. 2011.

[3] R. Moro, S. Agneessens, H. Rogier, and M. Bozzi, "Wearable Textile Antenna in Substrate Integrated Waveguide Technology," IET Electronics Letters, Vol. 48, No. 16,pp. 985–987, August 2, 2012.

[4] R. Moro, A. Collado, S. Via, A. Georgiadis, and M. Bozzi, "Plastic-based Substrate Integrated Waveguide (SIW) Components and Antennas," 42th European Microwave Conference 2012 (EuMC 2012), Amsterdam, The Netherlands, Oct. 28–Nov. 2, 2012.

[5] F.Alimenti, P.Mezzanotte, M.Dionigi, M.Virili and L.Roselli, "Microwave Circuits in Paper Substrates Exploiting Conductive Adhesive Tapes ," IEEE Microwave and Wireless Components Letters, Vol. 22, No. 12, December 2012.

[6] R. Garg, I. Bahl, M. Bozzi, *Microstrip Lines and Slotlines*, 3rd ed. Norwood, MA, USA: Artech House, 2013.

[7] K. Wu, D. Deslandes and Y. Cassivi, "The Substrate Integrated Circuits - A New Concept for High-Frequency Electronics and Optoelectronics, "*TELSKIS 2003*, Nis, Serbia and Montenegro, pp. Oct. 2003.

[8] J. E. Rayas-Sanchez and V. Gutierrez-Ayala, "A General EM-Based Design Procedure for Single-Layer Substrate Integrated Waveguide Interconnects with Microstrip Transitions", *IEEE MTT-S Int. Microwave Symp. Dig.*, Atlanta, GA, Jun. 2008, pp. 983-986.

[9] X.Chen, K. Wu, D. Drolet, "Substrate Integrated Waveguide Filter with Improved Stopband Performance for Satellite Ground Terminal," Microwave Theory and Techniques, IEEE Transactions on Vol 57 ,pp.674-683, 2009.

[10] M. Bozzi, A. Georgiadis, and K. Wu, "Review of Substrate Integrated Waveguide (SIW) Circuits and Antennas," *IET Microwave Antennas and Propagation*, Vol. 5, No. 8, pp. 909– 920, June 2011.

[11] F. Giuppi, A. Collado, A. Georgiadis, and M. Bozzi, "A Compact, Single-Layer Substrate Integrated Waveguide (SIW) Cavity-Backed Active Antenna Oscillator," IEEE Antennas and Wireless Propagation Letters, Vol. 11, pp. 431–433, 2012.

[12] H.Abdelali, R.Bedira, H.Trabelsi, A.Gharsallah, S.Moscato, R. Moro, M. Pasian, M. Bozzi and L. Perregrini, "Innovative Technique for Substrate Integrated Waveguide Implementation on Paper Substrate," 14th Mediterranean Microwave Symposium (MMS 2014), Marrakech, Morocco, Dec 12-14,2014.

[13] H.Abdelali, R.Bedira, H.Trabelsi and A.Gharsallah, "Development of Substrate Integrated Waveguide BPF for Wireless Sensor Network Applications," International Journal of Innovative Engineering and Emerging Technology (IJIEET), Vol. 2, Issue 2, May-June 2016.

[14] Q.Wang and J.Bornemann, " Triple-Pass-Band, Dual-Stop-Band UWB Antenna With Substrate integrated Waveguide Resonators," Microwave and optical Technology Letters, Vol. 56, No. 6, June 2014.

[15] S.Moscato, R.Moro, M.Pasian, M.Bozzi and L.Perregrini, "Innovative manufacturing approach for paper-based substrate integrated waveguide components and antennas," IET Microw. Antennas Propag., 2016, Vol. 10, Iss. 3, pp. 256–263.

[16] M.Bozzi, L.Perregrini, and K. Wu, "Modeling of conductor, dielectric and radiation losses in substrate integrated waveguide by the boundary integral-resonant mode expansion method ," IEEE Trans. Microw. Theory Tech., 2008, 56, (12), pp. 3153–3161.

[17] M.Bozzi, M.Pasian.,L.Perregrini and al. , " On the losses in substrate integratedwaveguides and cavities ," Int. J. Microw. Wirel. Technol., 2009, 1, (5), pp. 395–401.

[18] R. J , Cameron., C.M Kudsia. and R.R., Mansour, " Microwave filters for communication systems: fundamentals, design and applications," (John Wiley and Sons, Inc., New Jersey, 2007).

Evaluation and Comparison of Binary Trie base IP Lookup Algorithms with Real Edge Router IP Prefix Dataset

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***Abstract*—Internet network is comprised of routers that forward packets towards their destinations. IP routing lookup requires computing the Best-Matching Prefix. The main Functionality of Router is finding the Appropriate Path for Packet. There are many Algorithms for IP-Lookup with different Speed, Complexity and Memory usage. In This Paper Three Binary Trie algorithms will be considered for Performance Analysis. These algorithms are Priority-Trie, Disjoint Binary and Binary Trie. We consider three parameters for comparison, these parameters are Time, Memory and Complexity of Algorithms. For performance analysis, we develop and run algorithms with real Lookup-Tables which were used in an edge router.**

Keywords—Binary Trie; IP-Lookup; Running Time; Memory Usage; Complexity

I. Introduction

Routers Receive Packets and Analyze them. Routers Extract Source and Destination IP Address from packets. This equipment looks for Destination IP Address in a Table with a lot of IP Prefixes, Output Interfaces and Next-Hops IP Address, then Forwards Packets to next-Hop through the output interface. Routers fill Lookup Table With many Different Routing Protocols that are Standard. IP Lookup is a bottleneck of Routing [1]. There are two Versions of IP Address, IPv4 & IPv6. In this Paper concentration is on IPv4 that is universal and popular. IPv4 structure consists of 32 bits and is shown with 4 decimal digits that are separated by dot [2]. There is Two Type of IPv4 addressing that are defined in (a) and (b).

A. Classful IP Addressing

IPv4 Structure divided by two portions. More Valuable bits portion is network section and the other one is for Hosts. Network bits are called "Address Prefix". For showing IP Address Prefix, bits related to Network are used and for other bits "*" is used, for example 1000001001010110* is an IP Address Prefix that consist of 2^{16} IP Address that are started by this IP Address Prefix. Address Prefix is shown in Decimal like 130.86/16 [1]. Routers should search and Forward Packets with IP address Prefix.

TABLE I. Forwarding Table Example [1]

Destination Address Prefix	Next-hop	Output interface
24.40.32/20	192.41.177.148	2
130.86/16	192.41.177.181	6
208.12.16/20	192.41.177.241	4
208.12.21/24	192.41.177.196	1
167.24.103/24	192.41.177.3	4

Some Classes are defined in this addressing structure, for example IP class A, B & C are shown in fig (1).

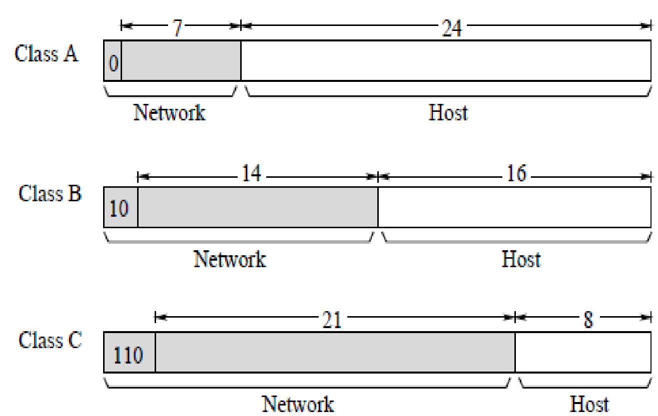

Fig. 1. Classful IP Addressing [1]

B. CIDR IP Addressing

This addressing method is proposed for efficient use of address space in IPv4. In classful addressing, there are limited classes but in CIDR addressing method, network bits are variable and specify with Mask. IP address and Net Mask are operated by XOR and network bits extracted.

Routers must use Longest Prefix Matching for IP Lookup that is shown in fig (2).

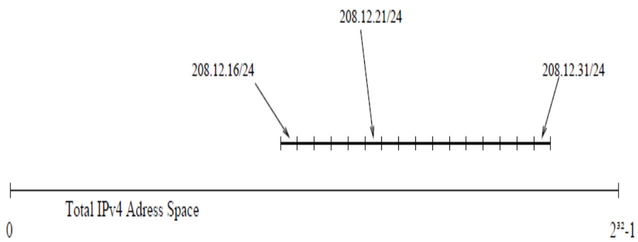

Fig. 2. CIDR Addressing in IPv4 Space [1]

Paper [5] proposed an optimized method for IP Lookup Table management with considering of memory complexity.

In this Paper, three algorithms which are Binary Trie Base are developed and run for twelve times, and evaluate algorithms in a situation with real IP Lookup Table Data. This IP lookup Table data is collected in 4 period of time and data variable is considered. Datasets are used for each algorithm. In section 2, the algorithms are described and in section 3, the situations of development and simulation are described and in section 4, the results and Charts are shown then in the last section there is a conclusion .In the last section there is a conclusion about the results.

Router processes entry IP Packet and extract IP address. It uses IP address prefix or IP network section and looks for it in lookup table then forwards packet to specified output interface. Totally there are two type IP Lookup algorithms, hardware and software base. table (II) shows IP lookup algorithms.

TABLE II. TOW TYPE IP LOOKUP ALGORITHMS (HARDWARE AND SOFTWARE)

Hardware Base Algorithms	**Software Base Algorithms**
DIR-24-8-BASIC Scheme	Binary-Trie
DIR-Based Scheme with Bitmap Compression (BC-16-16)	Path Compressed Trie
Ternary CAM for Route Lookup	Multi-Bit Trie
Algorithms for Reducing TCAM Entries	Level Compression
Reducing TCAM Power – Cool CAMs	Lulea Algorithm
TCAM-Based Distributed Parallel Lookup	Tree Bitmap Algorithm
	Tree-Based Pipelined Search
	Binary Search on Prefix Range

Nowadays SDN separates Data Plane and control Plane, so software base algorithms got important contrary to advantage of Hardware base algorithms. SDN make service providing agile [3]. NFV try to implement network functions as software and virtual [4]. Software base network simplify network entity. Because of software base network importance, three software base and basic IP Lookup algorithms are developed, Evaluated and compared in this paper.

Three basic and main software base IP Lookup algorithms are Binary trie, Disjoint Binary Trie & Priority Trie that other software base algorithms derived from them.

C. Binary Trie algorithm [2]

First, this algorithm reads IP Address Prefixes from IP Lookup Table and makes a Binary tree then looks for per entry packet IP address. The tree structure that this algorithm makes is shown in fig (3).

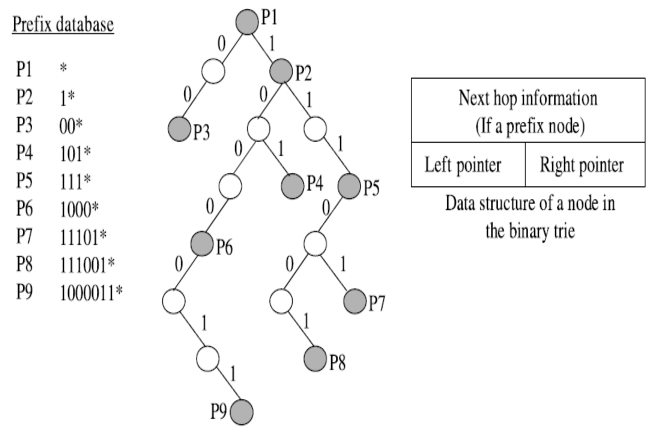

Fig. 3. Binary Trie [2]

- Binary Trie Prefix construction Algorithm

IP prefix binary tree construction needs a structure with three fields.

1) A Pointer to the left
2) A pointer to the right
3) A value with binary type

Preprocessing of IP lookup table to make sure all prefixes are in binary format. To begin, a software module reads each prefix from IP lookup file and a pointer creates as a root node then if current bit is 0 pointer goes to the left branch else if current bit is 1 pointer goes to the right branch. Pointer reads next bit and base on value does as mentioned algorithm before from the current node. In each IP address prefix last bit, pointer writes the prefix in value variable.

- IP Lookup algorithm base on binary tree

In first step, a pointer reads entry IP address valuable binary and if pointer sees 0 then points to left branch else if pointer sees 1 then points right branch. This algorithm goes on until pointer points a node that doesn't exist. if the pointer sees a node with value (not null) this prefix is longest prefix match for this entry IP address else if pointer sees last node with null value, it should register last node value as longest prefix matching that has seen before and has not been null.

- Insert node to the tree

For insertion also navigate the tree like construction and lookup algorithms and add value null for intermediate node and insert specified value for the last node of tree.

- Delete node from the tree

For this algorithm like making, lookup and insertion, tree should be navigated and deleted node and delete intermediate node until a node with not null value is seen.

Memory complexity depends on number of address prefix in lookup table and number of prefix bits O(NW). N is number of prefixes in lookup table and W is shown number of prefix bits. Memory complexity depends on memory speed and number of memory access. Algorithm Complexity depends on number of instructions that are run.

D. Disjoint Binary Trie [2]

This algorithm is similar to Binary Trie with a difference that there is a full binary tree and all leaves are prefix except intermediate node which is shown in fig (4).

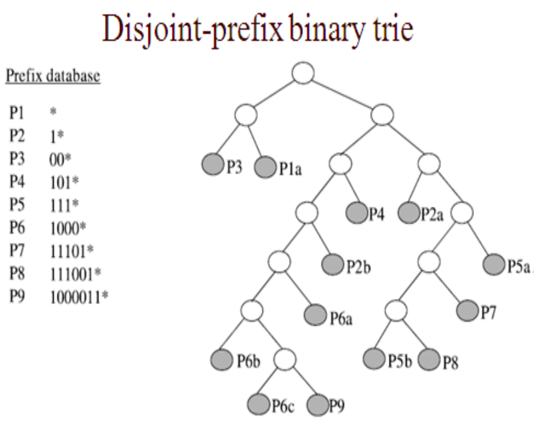

Fig. 4. Disjoint Binary Tree [2]

In this method pre-order tree navigation is done and if intermediate node has a not null value, registers and insert s to subtree. This algorithm use 128 node for tree and memory complexity increases but tree gets more structural.

E. Priority Trie Algorithm [6]

This algorithm like Binary Trie does but there is a difference in tree node arrangement that is done as descending mode in tree. Nodes with null value are deleted. In the binary tree, there is two problems, first existence of many nodes with null value and second Long and deep prefix with too delay in lookup, all these problems are solved in this algorithm.

First prefixes should sorted descending mode with considering of prefix length. A tree is made like binary tree. In this algorithm, intermediate node is not needed and where a prefix is set to each node until decrease tree navigation, fig(5) shows this concept.

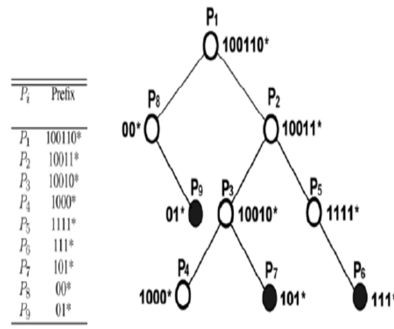

Fig. 5. Priority Trie [6]

In this algorithm a node with more prefix length in comparison of tree level, is called Priority node and seen as a white circle in fig(4) and a node with less prefix length in comparison of tree level, is called Ordinary and is shown with black circle in fig(5).

II. MATERIALS AND METHODS

In this paper, C++ language is used for IP Lookup algorithm Implementation. All IP Lookup table data are collected from an edge router in four different months. IP Prefixes have saved in a text file.

In this project a node is implemented by a class. This class consists of two pointers and a variable called value. Pointer is node class type and Value variable is array of 32 Boolean type variables.

An instance of class is defined to use in node construction for binary tree. In priority algorithm, a bit is defined to specify node type.

For calculating of memory complexity, number of nodes multiply used memory of per node therefore memory complexity of Binary tree is equal:

$$storage\ Coplx(bit) = (32 * 2 + Value.length * 16);$$
Each Node Complexity (1)

In Priority Trie algorithm 1 is added to the above equality. in 32 bit OS, a pointer occupies 32 bit and in 64 bit OS, a pointer occupies 64 bit that should be considered in memory complexity calculation. We use a 32 bit OS.

For calculating time, we run software and calculate spent time.

For calculating of algorithm complexity, we use the number of instruction for each IP lookup algorithm.

III. RESULTS

We have four IP Lookup Prefixes in text file and we read and make tree for different IP lookup algorithms.

A. 1th IP Lookup table

This dataset has 519998 prefixes.

TABLE III. FIRST THREE ALGORITHMS COMPARISON

	Time	Complexity	Memory(Hop*Mem)	Total Memory(Bit)
Binary	12140.63	59198146	312768	206786368
Disjoint	10250	60916464	403591	201097312
Priority	38812.5	69625952	204613	16521520

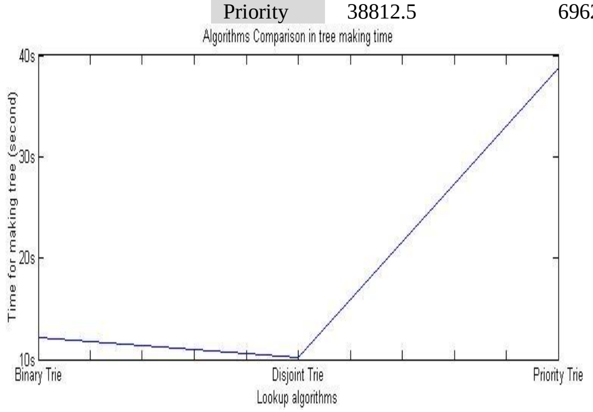

Fig. 6. Comparison of three algorithms In Tree making time (ms)

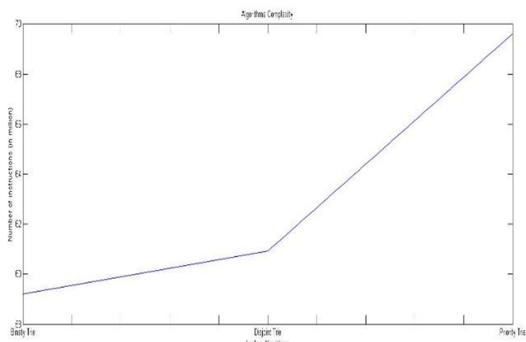

Fig. 7. Comparison of three algorithms Complexity

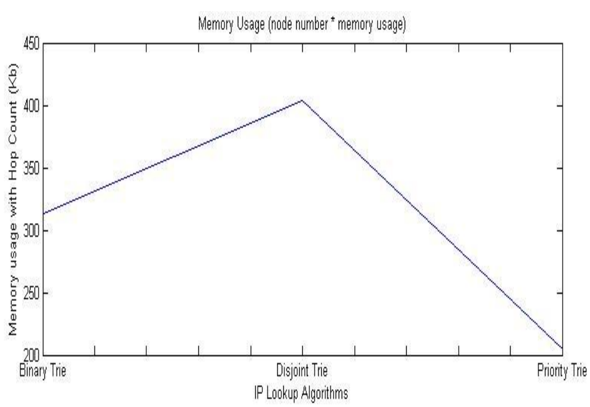

Fig. 8. Comparison of three algorithms In memory complexity

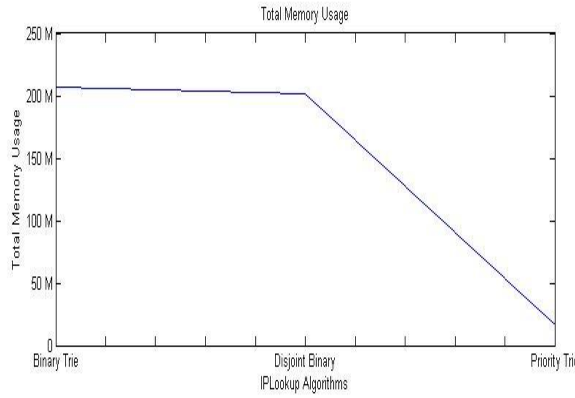

Fig. 9. Comparison of three algorithms In memory usage (bit)

B. 2th IP Lookup table

This dataset has 520000 prefixes.

TABLE IV. SECOND THREE ALGORITHMS COMPARISON

	Time	Complexity	Memory(Hop*mem)	Total Memory(Bit)
Binary	11875	57472334	314766	207073184
Disjoint	10109.38	59199886	407819	206869728
Priority	38750	67329984	206206	16588736

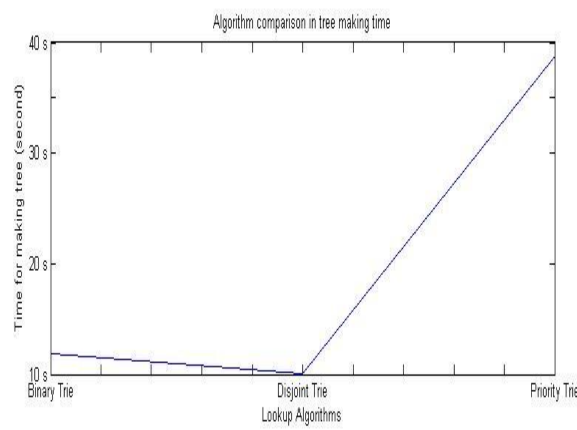

Fig. 10. Comparison of three algorithms In Tree making time (MS)

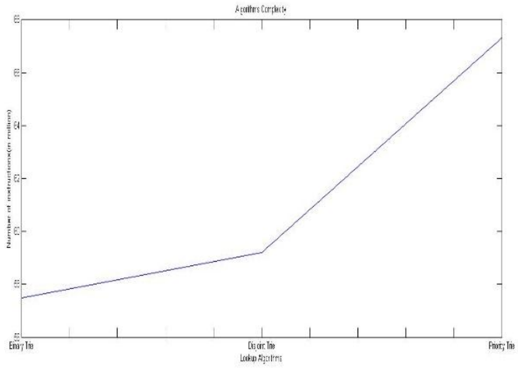

Fig. 11. Comparison of three algorithms Complexity

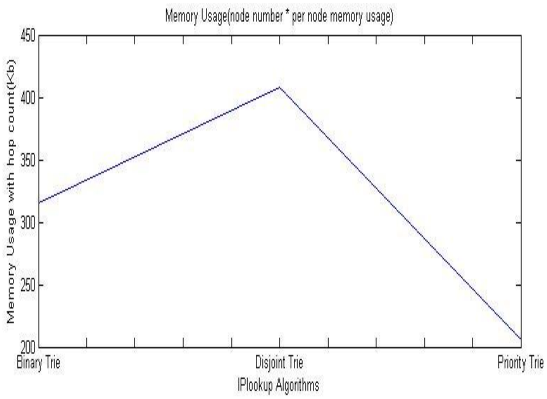

Fig. 12. Comparison of three algorithms In memory complexity

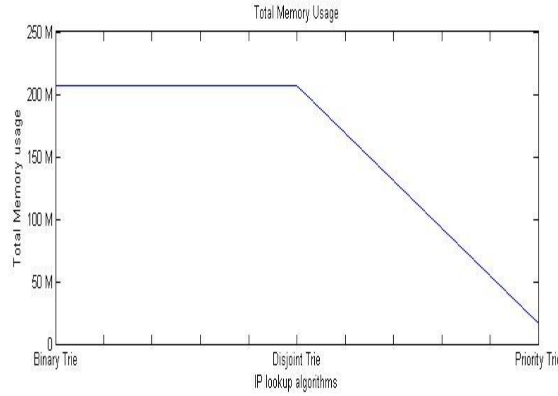

Fig. 13. Comparison of three algorithms In memory usage (bit)

C. 3th IP Lookup table

This dataset has 519995 prefixes.

TABLE V. THIRD THREE ALGORITHMS COMPARISON

	Time	Complexity	Memory(Hop*Mem)	Total Memory(Bit)
Binary	11296.88	58611469	327324	205794016
Disjoint	9750	60407101	429595	204547792
Priority	38046.88	68800571	208218	16820048

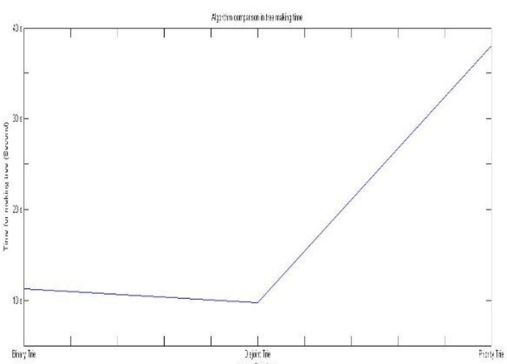

Fig. 14. Comparison of three algorithms In Tree making time (MS)

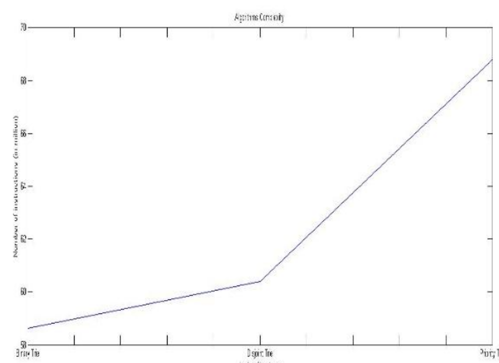

Fig. 15. Comparison of three algorithms Complexity

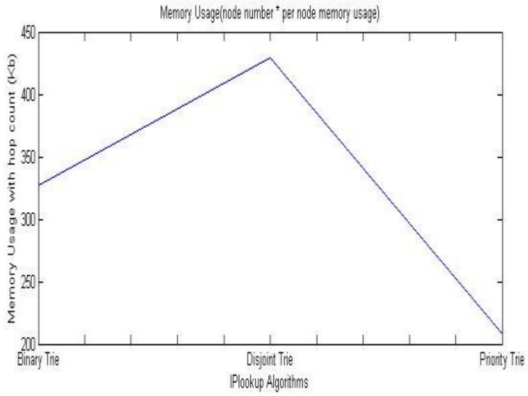

Fig. 16. Comparison of three algorithms In memory complexity

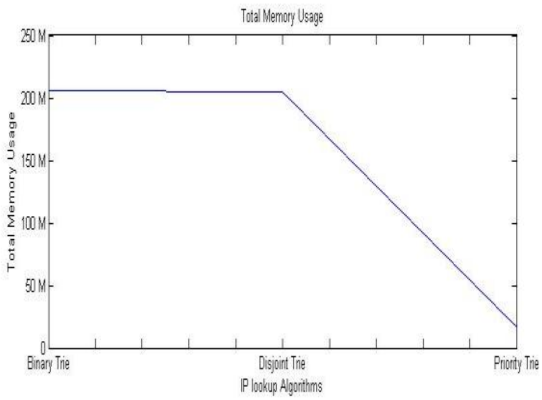

Fig. 17. Comparison of three algorithms In memory usage (bit**)**

D. 4th IP Lookup table

This dataset has 519998 prefixes.

TABLE VI. FOURTH THREE ALGORITHMS COMPARISON

	Time	Complexity	Memory(Hop*mem)	Total Memory (Bit)
Binary	12140.63	59198146	312768	206786368
Disjoint	10250	60916464	403591	201097312
Priority	38812.5	69625952	204613	16521520

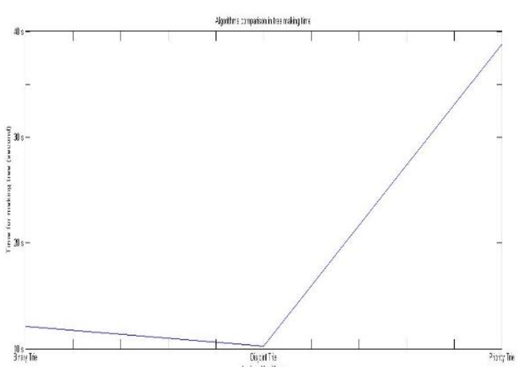

Fig. 18. Comparison of three algorithms In Tree making time (MS)

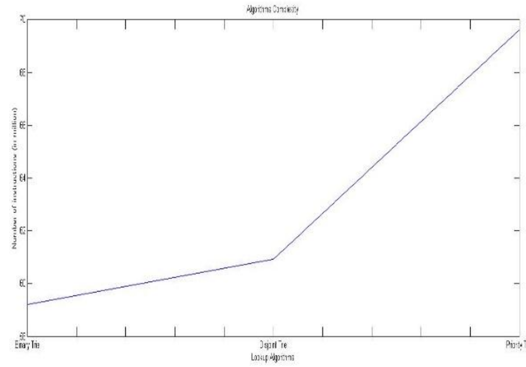

Fig. 19. Comparison of three algorithms Complexity

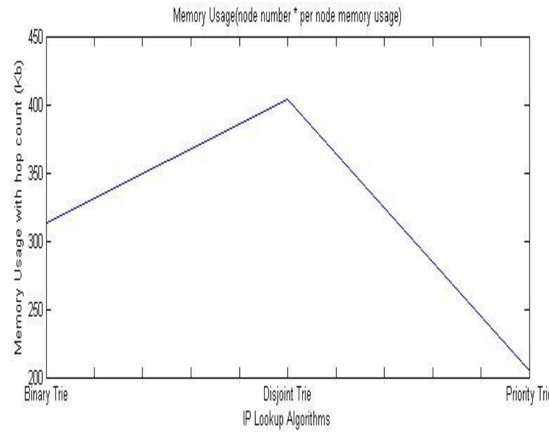

Fig. 20. Comparison of three algorithms In memory complexity

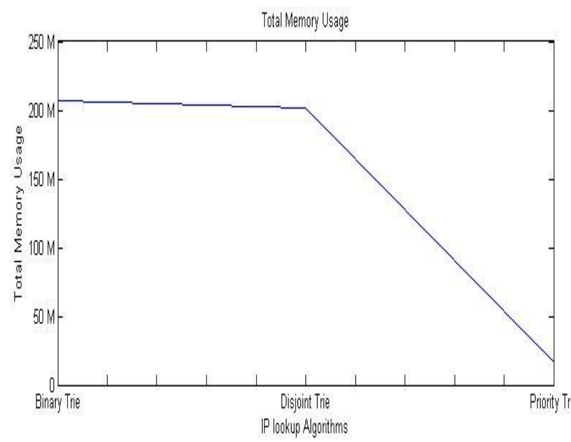

Fig. 21. Comparison of three algorithms In memory usage (bit)

IV. DISCUSSION

According to the results, Internet network is comprised of routers, that forward packets towards their destinations. IP routing lookup requires computing the Best-Matching Prefix. The results show that the Priority Trie algorithm performance is need more time to make tree in compared with other two algorithms because of sorting. Binary trie and Binary disjoint trie algorithms need similar time to make tree but if tree goes toward full binary tree, more similarity was seen and if tree goes toward light, more different time was seen.

From the point of algorithm complexity, Priority trie algorithm based on number of instruction is the most complex algorithm in comparison with the others.

Disjoint binary trie algorithm has the most memory usage because there are more leaves in comparison with the others. Priority algorithm has the least memory usage in comparison because deleted leaves value is null.

Priority trie IP lookup speed is more than the other algorithms. When there is longer prefix, Priority trie algorithm search speed is much better than the others.

For the future work, two subjects are proposed:

A. Evaluation of binary trie base algorithms with use of IPv6,

B. Evaluate the other algorithms that are described in this paper for IPv4.

References

[1] M. A. Ruiz-Sanchez, E. W. Biersack and W. Dabbous, "Survey and taxonomy of IP address lookup algorithms," in IEEE Network, vol. 15, no. 2, pp. 8-23, Mar/Apr 2001.

[2] doi: 10.1109/65.912716.

[3] H.Jonathan Chao, Bin Liu, “High Performance Switch And Routers,” in Book 2007.

[4] A. Lara, A. Kolasani, and B. Ramamurthy, "Network innovation using OpenFlow: a survey", Communications Surveys & Tutorials, vol. 16, no. 1, pp. 493-512, 2014.

[5] M. K. Shin, Y. Choi, H. H. Kwak, S. Pack, M. Kang and J. Y. Choi, "Verification for NFV-enabled network services," Information and Communication Technology Convergence (ICTC), 2015 International Conference on, Jeju, 2015, pp. 810-815.

[6] doi: 10.1109/ICTC.2015.7354672.

[7] Kun Huang, Gaogang Xie, Yanbiao Li, Dafang Zhang, “Memory-efficient IP lookup using trie merging for scalable virtual routers” in Journal of Network and Computer Applications, vol. 51, pp.47-58, May 2015.

[8] H. Lim ; Ewha Womans University, Seoul ; C. Yim ; E. E. Swartzlander Jr, “Priority Tries for IP Address Lookup” in IEEE Transactions on Computers, vol. 59, no.6, February 2010.

Flying Ad-Hoc Networks: Routing Protocols, Mobility Models, Issues

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***Abstract*—Flying Ad-Hoc Networks (FANETs) is a group of Unmanned Air Vehicles (UAVs) which completed their work without human intervention. There are some problems in this kind of networks: the first one is the communication between (UAVs). Various routing protocols introduced classified into three categories, static, proactive, reactive routing protocols in order to solve this problem. The second problem is the network design, which depends on the network mobility, in which is the process of cooperation and collaboration between the UAV. Mobility model of FANET is introduced in order to solve this problem. In Mobility Model, the path and speed variations of the UAV and represents their position are defined. As of today, Random Way Point Model is utilized as manufactured one for Mobility in the greater part of recreation situations. The Arbitrary Way Point model is not relevant for the UAV in light of the fact that UAV do not alter their course and versatility, speed quickly at one time because of this reason, we consider more practical models, called Semi-Random Circular Movement (SRCM) Mobility Model. Also, we consider different portability models, Mission Plan-Based (MPB) Mobility Model, Pheromone-Based Model. Moreover, Paparazzi Mobility Model (PPRZM). This paper presented and discussed the main routing protocols and main mobility models used to solve the communication, cooperation, and collaboration in FANET networks.**

Keywords*—*FANET; Ad-hoc Network; UAVs; MANET; Mobility Model; Networking Model

I. Introduction

FANETs (Flying Ad-hoc Networks) is a group of Unmanned Air Vehicle (UAVs) communicating with each other with no need to access point, but at least one of them must be connected to a ground base or satellite [1]. UAVs work without human help, like autopilot. This is because cheaper and small wireless communicating devices, the in recent years, many research fields from academia and industry make attention on FANETs. Now, FANETs are used in various applications such as military and civil applications [1], such as managing wildfire [2] and disaster monitoring [3]. As each type of network has its own specification and using the protocol depends on this specification, it is important to use a reliable protocol for this kind of networks and check their performance using simulation. Two factors affect protocol simulation: the first one is mobility model, and the second one is the communicating traffic pattern, among others. This paper focuses on the routing protocols and mobility models that have been used in the FANET network to solve communication, cooperation and collaboration problem between UAVs.

The rest of this paper is organized as follows. Section II gives literature review of specific ad-hoc network with flying nodes, Section III presents the FANET characteristics, and section IV presents themainrouting protocols used in FANET. Mobility models recently used in the FANETs have been displayed in Section V. Section VI concludes this study.

II. Ad-Hoc Networks with Flying Nodes

FANET are a special case of mobile ad hoc networks (MANETs) [4]. FANET are a network with nodes –UAVs- flying in the sky [1], which can automatically fly without human help. It consists of two parts, ad-hoc network and access point like a satellite or ground base to connect with the network in at least one of them, according to carry the data from one ground base to another. The network that its link is established between each UAV and an access point is not specified as FANET network. Using multi-UAVs in this network family reflects many advantages on this network [5]:

1) Minimize the completion time for a request: when many UAVs processes a request, it will be ready faster than one UAV.

2) Minimize the cost and the maintenance: using small UAVs is cheaper than one big UAV, and the maintenance is lower as well.

3) Increase Scalability: It can maximize the operations done by the network by adding more UAVs to the network dynamically according to the request needs.

4) Increase sustainability: the network can work continuously even if one UAV fails since other UAVs can perform the task.

Since multi-UAVs have many other advantages like the dynamic topology of the network, it still has the problem of communication between UVAs in FANETs. This problem is solved this problem using two types of protocols for communication first one is between the UAVs itself, and the other between the UAV and the access point [4]. In UAVs communication, each UAV communicates with the other UAV directly or using multi-hop communication. In the other kind of communication, the UAV create the connection with an infrastructure like a ground base or satellite to transfer the data.

III. FANETs Characteristics

In FANETs, the node became UAV [1]. The single UAV system cannot create an FANETs network; therefore, it is valid for multi-UAVs systems. On the other hand, it cannot call any multi-UAVs systems FANETs; if each UAV is connected to a base ground or satellite, it does not have a FANETs network. FANETs must contain UAVs which communicate between each other using ad hoc network and at most one of them connect to infrastructure. In MANET and FANETs, there are many common design considerations. In the following points, some FANETs characteristics are displayed in a detailed manner [1]:

1) Node Mobility

In node mobility, the degree is larger than MANET and VANET. The UAV has a speed of 30-460 km/h, and this speed causes the communication problem between UAVs [1].

2) Mobility Models

In many mobility models, the flight plan is predetermined and at each step there is a change, recalculation for the map take place [1]. Other models are using random speed and directions for the UAVs. In section V, Mobility models described in details.

3) Node Density

The average number of UAVs in some area is called Node Density. In FANETs, it must be a sparse density with large distances between them according to the nature of flying [1].

4) Network Topology

In order to the higher mobility, degree, topology changed frequently [1]. The communication between UAVs has also broken frequently; because the higher speed, or if the UAV is out of the range because location changing occurs rapidly. At each UAV connection failure, update processing is needed.

5) Radio Propagation model

Here, according to the nature of the environment in FANETs and the large distances between UAVs. The UAVs uses a line-of-sight between them and with a ground base. In contrast with MANET, it does not use any radio signal between nodes.

6) Power Consumption and network lifetime

Network lifetime is an important issue for the network, which consists of battery-powered computing devices. Communication hardware used in FANETs is powered by UAV energy source itself. In case of this, FANETs designs may not be power sensitive, in contrast with MANET applications. But it stills a problem in mini UAVs [6].

7) Localization

Localization means determining the location for each UAV. According to high speed and frequently change in place, there is a need for highly localization information with small intervals of time. Using GPS, the information about the new locations will be propagated to the network each one second, and this is not sufficient. Therefore, each UAV must be containing a GP and Initial measurement unit to broadcast his location to all UAVs in the network at any time.

IV. ROUTING PROTOCOLS USED IN FANETS

There are many routing protocols used in wireless and ad-hoc networks [7, 8], such as flooding, dynamic source routing, and pre-computed routing. But due to the characteristics of UAVs like speed and rapid changes in links between nodes, these protocols need to be modified and the others will be established to adopt this network issues. Using the following protocols, FANETs network has the property of dynamic adding nodes and deleting nodes from the network due to their needs. These protocols can be viewed as four main classes [5].

1) Static protocols: They contain a routing table that is not edited at any time.

2) Proactive protocols: It contains a routing table for each node that is refreshed periodically.

3) Reactive Protocols: It is called on-demand routing protocol, which fills the routing tables when there is a need to send data and the path is not known.

4) Hybrid Protocols: It takes advantages from proactive and reactive protocols.

STATIC ROUTING PROTOCOLS

In this kind of routing protocol, firstly the information for UAVs is computed and loaded to each UAV. It cannot be changed during the operation, and the topology of the network must be fixed also [9]. This leads to minimizing the number of communication links between UAVs or between UAV and the ground base. There is no fault tolerance to provide a dynamic environment for the network in case of the failure of some UAVs or access point because they must wait until the end of the mission to fix the failure occurs. Instead of these problems, some routing models are established for FANETs network:

- Load Carry and Deliver Routing (LCAD)[5]

One of the most popular secure routing protocols used in FANETs is LCDR [5]. In this model, communication between UAVs does not occur. This protocol is used to transfer data from a ground base to a ground base using flying UAVs with single hop communication; it is useful to transfer images or videos. Firstly, the data loaded from a source access point to the UAV and the UAV moves to the destination access point to get it the data. In terms of security, this model is secure; because there are no hops during the transfer of data. The time needed to deliver the datafrom the source ground base to the destination ground base depends on the speed of UAV and the distance between the source and destination access points, another suggestion to decrease the transfer time more than one UAV can be used for the same source and destination, or increase the speed of UAVs, and divide the network to smaller LCAD sub-networks. Figure 1 shows LCAD routing technique.

- Multilevel Hierarchical Routing (MLH) [5]

Due to big FANETs, the network consists of UAVs with different attributes; this model organizes the process of sending the data between a ground station and the UAVs [5]. MLH divides the UAVs into clusters; each cluster performs the operations in specific areas, with a cluster head (CH) for each cluster to communicate between other clusters and their access point. This model is useful when UAVs is ordered in different characteristics, and the area of the network is large, and the network has many UAVs. Figure 2 shows MLH routing technique.

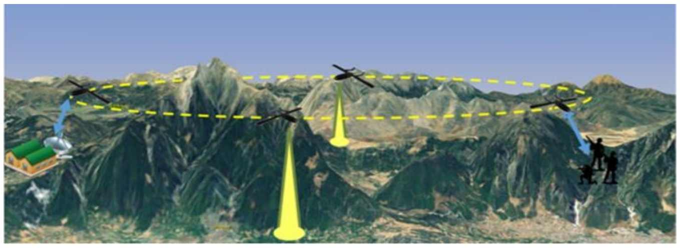

Fig. 1. Load Carry and Deliver Routing [5]

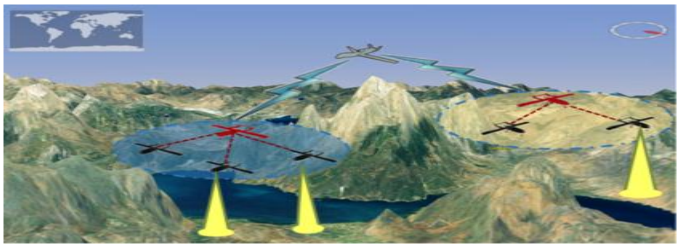

Fig. 2. Multilevel Hierarchical Routing [5]

- Data-Centric Routing (DCR) [5]

This kind of routing protocols used when some data needed by many UAVs in the network, in this case,one-to-many communication are preferred than one to one data transmission [10, 11]. In this routing protocol, the ID for UAVs is not important; here the routing is done with respect to the data, not to the ID of UAVs that requests it. DCR UAVs are divided into clusters and works as follows, when a UAV or a ground station needs data such as (Take a photo for region A if there is more than one tank on the ground), this request will be sent to all UAVs and each one decides if it must collect the data or not, and send the data to other UAVs, Figure 3 shows DCR technique. The disadvantage of this technique is the redundant data sent on the network, but there are advantages of this technique like:

- **Space decoupling** communicating UAVs and ground station does not need to know the ID and the location of each other.
- **Time decoupling** there is no need to be UAVs online all the time.
- **Flow decoupling** in case there is an interaction in the outside, message sending process is not blocked between UAVs.

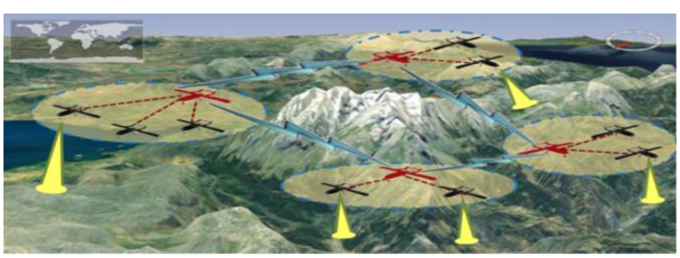

Fig. 3. Data-Centric Routing [5]

PROACTIVE ROUTING PROTOCOLS (PRP)

This technique of routing using a table contains all the information about all nodes in the network, thus each node knows all the things about each other in the network. This technique has one main advantage, the table for each node always has the latest information about the other nodes, but we take in our mind that this technique needs a bandwidth because the overhead of the updated messages for the tables, therefore PRP is not applicable for highly mobile or big networks -FANETs-. Due to the control of bandwidth in FANETs network, some routing protocols in modified version can be used in order to change the topology for the nodes.

- Optimized Link State Routing (DLSR) [12]

In OLSR, each node has the information about their neighbors. Two kinds of messages are used in the network. The first one is hello messages, which is sent periodically to check the connectivity with neighbors in one hop in the communication range, and then each UAV sends another one to hop hello message to the neighbors at another time. The second one is the control messages that issued to refresh the information about the topological order for the network; therefore, each node refreshes its information about paths to all other nodes in the network periodically. In this solution, there is a big overhead. In order to reduce this overhead, Directional Optimize Link State Routing arises (DOLSR) [13].\, in which Multipoint Relay is used. Therefore, when any node needs to broadcast the information to other nodes, it will select an MPR to forward the routing messages. Figure 4 shows MPR model.

The process of selecting the MPR is the most important step in OLSR protocol. [13] Generally speaking, as the MPR can be as small as possible, the overhead will decrease accordingly. To this respect, a new mechanism is proposed for reducing the number of members of MPR. Figure 5 shows a diagram for the proposed DOLSR. At any sending data step, the sender calculates the distance to the destination, then if the distance is greater than the maximum distance that can be achieved using the directional antenna (Dmax/2), DOLSR algorithm will be used in this case or when the Omni-directional antenna cannot achieve the destination. Otherwise, OLSR will be used [13].

- Destination-Sequenced Distance Vector (DSDV)

Using this routing protocol, each UAV must know everything about all other UAVs in the network, but with a small modification [14].The difference between this technique and the simple proactive approach is that this approach uses a sequence number assigned by the destination node in order to eliminate the loop of routing occurred by the changes of the topology for the network. Then each UAV with a higher sequence number is better than the UAV with a lower sequence number. Simplicity and loop-free are the main advantages in Destination-Sequenced Distance Vector routing protocols. However, on the other hand, DSDV has the same drawback of OLSR, the overhead in the network when updating the tables.

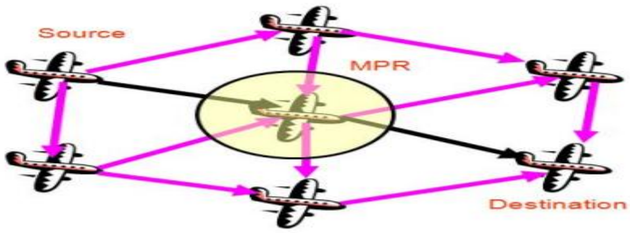

Fig. 4. MPR Model [13]

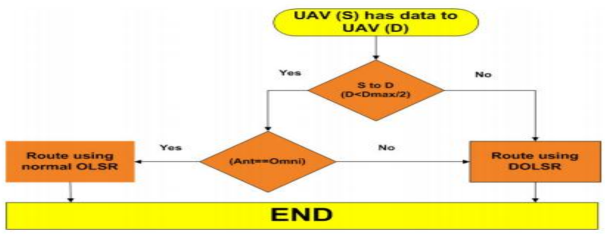

Fig. 5. DOLSR Algorithm [13]

Reactive Routing Protocols

RRP is also called on-demand routing protocol, which means that the path between nodes is established when there is a request [5]. RRP comes up to solve the overhead problem in PRP; there is no need to periodically calculate the paths for each node. In this technique, there are two types of messages which are RouteRequest and Route Reply. RouteRequest is sent from the source node to all neighboring nodes using flooding techniques to scan the path, and each node uses the same strategy until it reaches the destination. The second one is a message generated by the destination node and goes to the source using the unicast technique. In this case, each node saves the current using one path not all paths, and there is no need to refresh all tables in the network.

Bandwidth efficiency is the main advantage to using this technique. On the other hand, it will be slower than PRP because of the time for finding the path.

- Dynamic Source Routing (DSR)[14]

It is a simple RRP used in multi-hop wireless networks [15]. In this technique, each UAV sends data that includes a request ID with the data and then sends the data to avoid any confection that may occur in the media. DSR differs from other routing protocols; each source node saves the path to the destination in the header of the data. A maintenance process needed when some hop failure occurs in the network, if the new route does not found, a new recalculation process will begin to find another path. This routing protocol was implemented by Brown et al. In [16], and they concluded that finding a new route in the UAV network with DSR cannot be easy.

- Ad-hoc On-demand Distance Vector (AODV)

It is a reactive protocol that has some characteristic as DSR with differences in the routing table [17]. DSR, as mentioned above, saves the complete path from each node to any other node in the network, the contrast with AODV that saves one record for each node in the table. The second difference is in the process of sending the data, DSR saves the complete path with the data, but AODV saves just the next hop which maximizes the bandwidth in the network.

AODV protocol has three phases in sending the packets over the network. Any node that needs to send data, the discovery process takes place to discover the path from the source to the destination. This process is useful for loop-free. To maximize the freshness of the paths, it always uses a sequence number at each step that will be refreshed with the inner nodes in the network. When the route is discovered, then the second phase works, which is transmitting the data. In order of network failure, routing maintaining phase takes place to fix the failure or to refresh the ruts in the tables.

In a high mobility network, this congestion increases due to the need to refresh the routes more frequently. Thus, network congestion is an issue with AODV during the route determination phases. To solve this, Time Slotted On-demand Routing (TSOR) arise [18]. To decrease the communication between the UAVs, therefore, the collision during routing will be decreased. TSOR is based on AODV, in addition, to including a time component to the algorithm, as in slotted ALOHA, each UAV have a time-slot can send their data within. The communication occurred between all other nodes in the network not in the neighbor UAVs within the time-slot.

V. Mobility Models Used In FANETs

The mobility of a network depends on two basic parts, nodes location and velocity change in a time [19]. Nodes movement can be described as mathematical equation or simulation. Using simulation environment in mobility modeling gives us more accurate results, and gives solutions to more complex problems. Figure 6 shows some of the Mobility modelings that are used in FANETs network.

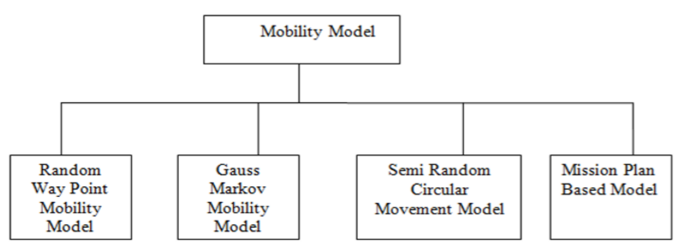

Fig. 6. Some of Mobility Models [23]

- Random Way Point Mobility Model[20]

The time pause between the changes in node direction and speed are included in Random Way Point Mobility Model [20]. UAVs in this Model move in random locations in a specific area, it is free in their movements within the simulation are independently from any other UAVs in the region. In [21] UAVs movements depend on specific probabilities. Because aircraft do not change their direction and speed rapidly and cannot stop in the sky period of time, this model is not suitable for aircraft. RWP is based on three actions: turn right, turn left, and going. Figure 7 shows RWP model.

- Gauss-Markov Mobility Model [19]

GMM model uses one tuning parameter to vary the degree of randomness in the mobility pattern [19]. For ad hoc network protocol simulation, this model has been used [22] and in swarm behavior. Here the simulation area is variation in contrast with RWP Model.

In GMM model, each node is initially set to a specific speed and direction, and then at each period of time, the movement will update the direction and the speed for the UAVs. The speed and direction are calculated based on the last position in order to the high velocity, as shown in Figure 8.

- Semi-Random Circular Movement Model [23]

This model is developed for the UAVs which their moves are in curving manner [19]. This technique is used to simulate UAVs to capture some information about some regions by rotating around the area specified. Thus, each UAV is monitoring part of the area where the object is wanted on it, as shown in Figure 9.

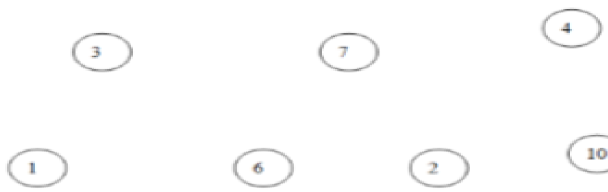

Fig. 7. Random Way Point Mobility Model [23]

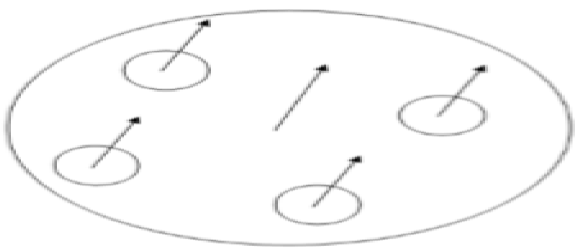

Fig. 8. Gauss-Markov Mobility Model [19]

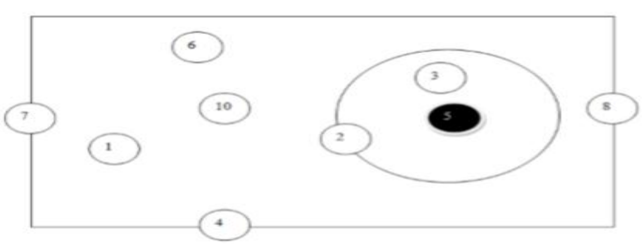

Fig. 9. Semi-Random Circular Movement Model [23]

- Mission Plan-Based Model [23]

In MPB model, the flight plan info is predefined and the aircraft can go ahead with this plan. It implies that the aircraft moves along the planned path each time, wherever the aircraft can reach mission space and the potential target location data is accessible [19], as shown in Figure 10. In the MPB mobility model, when the time is over, the mobility files are created and updated. For every aircraft, beginning and ending purpose are arbitrarily designated whereas rate and flight time are given. If an aircraft reaches the destination before flight time is over, it starts a new flight trip by change its direction and continuous flying.

- Pheromone-based model [20]

Pheromone model takes into account the area specified for each UAV and the pheromones guide UAV developments. Each UAV marks the zone that it checks on the guide, and imparts the pheromone guide to other UAVs. In order to expand the scope, UAVs incline toward the development through the zone with that does not discover yet. It was demonstrated that the utilization of a run of the mill MANET versatility model may bring about an undesirable way gets ready for helpful UAV applications, it was likewise watched that the irregular model is strikingly straightforward; however it prompts common results [25]. However, the pheromone base model has extremely dependable checking properties. With the pheromone show, a pheromone guide is utilized to manage UAVs. The flying machine trade data about their examined territory, and as indicated by what they choose, they turn left, right or proceed. Figure 11 shows PBM.

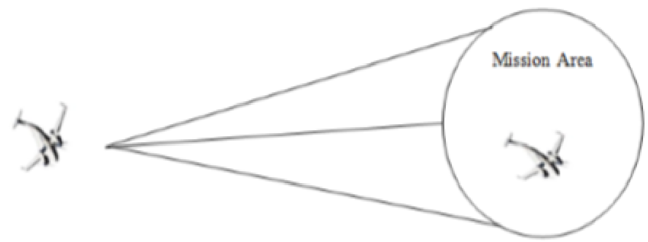

Fig. 10. Mission Plan-Based Model [23]

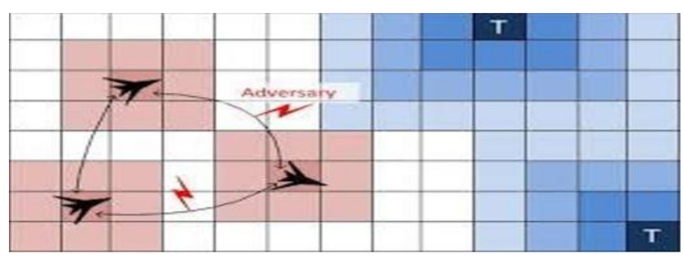

Fig. 11. Pheromone-based model [20]

- Paparazzi mobility model (PPRZM) [20]

The paparazzi portability model is a stochastic versatility demonstrate that the copies paparazzi UAV conduct in light of the state machine. PPRZM has nearer conduct to the genuine follows, and then RWP.PPRZM can be utilized to assess any correspondence, convention with regards to swarms of synergistic UAVs since it bears a practical development situation [20]. As a case in point, it might be utilized to contrast a few steering conventions all together to locate the suitable one for each UAV advertisement tothesystem. In addition, PPRZM can adjust to a mission since it assembles most UAV conceivable development by changing the likelihood of every development sort as required [25].

VI. Conclusion

In this paper, FANETs Literature review has been undertaken, Also, FANETs characteristics have been addressed, Then FANETs routing protocols have been discussed. Moreover, Mobility is the most challenging problem for FANETs. Different mobility models have been discussed that is solvedcommunication problems inside offrequent topology changesin FANETs networks. Furthermore, communication, cooperation, and collaboration are the most challenging design issues for multi-UAV systems. In this paper, ad-hoc networks between UAVs are surveyed as a separate network family, Flying Ad-hoc Networks (FANETs). Mobility models are discussed in details like Random Way Point, Gauss-Markov Mobility, Semi-Random Circular Movement, Mission Plane-Based, Pheromone-Based and Paparazzi Mobility model. Table 1 shows a comparison between routing protocols based on, nature, communication between UAVs and feature.

TABLE I. COMPARISON BETWEEN FANETS ROUTING PROTOCOLS

Routing Protocol	Nature	Communication between UAVs	Feature
Load Carry and Deliver Routing (LCAD)	Static	No, Just between the UAV and ground base	Secure
Multilevel Hierarchical Routing (MLH)	Static	The connection between UAVs in each clusterAnd between clusters and GB by CH	Minimize the overhead.
Data-Centric Routing (DCR)	Static	The connection between UAVs in each clusterAnd between clusters and GB by CH	The ID for UAV does not the matter
Directional Optimized Link State Routing (DOLSR)	Proactive	Not all UAVs. Between the UAV and MPR.	Lower end to end delay
Time Slotted On-demand Routing (TSOR)	Reactive	Yes.	Prevent the collision

REFERENCES

[1] I Bekmezci, OK Sahingoz, Ş Temel,"Flying ad-hoc networks (FANETs): A survey." Ad Hoc Networks 11. No 3 1254-1270.(2013).

[2] C. Barrado, R. Messeguer, J. López, E. Pastor, E. Santamaria, P. Royo, Wildfire monitoring using a mixed air-ground mobile network, IEEE Pervasive Computing 9 (4) (2010) 24–32.

[3] I. Maza, F. Caballero, J. Capitán, J.R. Martínez-De-Dios, A. Ollero, “Experimental results in multi-UAV coordination for disaster management and civil security applications”, Journal of Intelligent and Robotics Systems 61 (1–4) , 2011, 563–585.

[4] K. kanta, M. sunil, S. basant, “A Brief Survey of Mobility Model for FANET”, National Conference on Innovative Trends in Computer Science Engineering held at BRCMCET(ITCSE-2015)

[5] OKSahingoz. “Routing ptocols in flying Ad-hoc networks (FANETs): Concepts and challenges”. Journal of Intelligent & Robotic Systems, pp. 513-27.April 2014

[6] A. Purohit, F. Mokaya, P. Zhang, “Collaborative indoor sensing with the sensorfly aerial sensor network”, in: Proceedings of the 11th International Conference on Information Processing in Sensor Networks, IPSN, ACM, New York, NY, USA, 2012, pp. 145–146.

[7] MT.Hyland, “Performance evaluation of ad hoc routing protocols in a swarm of autonomous unmanned aerial vehicles”. PhD Thesis, Air Force Institute of Technology (2007)

[8] Gu, D.L., Pei, G., Ly, H., Gerla, M., Zhang, B., Hong, X.,“UAV aided intelligent routing for ad-hoc wireless network in single-area theater”. In: IEEE WirelessCommunications and Networking Conference(WCNC 2000), vol. 3, 2000, pp. 1220–1225.

[9] A Franchi, C Secchi, M Ryll, HH Bülthoff, PR Giordano,“Shared control: Balancing autonomy and human assistance with a group of quadrotor UAVs”. Robotics & Automation Magazine, IEEE. 19(3):57-68. September 2012.

[10] J Ko, A Mahajan, R Sengupta,“A network-centric UAV organization for search and pursuit operations”. In: IEEE Aerospace Conference, 2002, pp. 2697–2713.

[11] J López, P Royo, E Pastor, C Barrado, E Santamaria,“A middleware architecture for unmanned aircraft avionics”. In: ACM/IFIP/ USENIX InternationalConferenceonMiddlewarecompanion(MC‘07) (2007)

[12] T Clausen, P Jacquet, C Adjih, A Laouiti, P Minet, P Muhlethaler andL Viennot,“Optimized link state routing protocol (OLSR)”, 2003.

[13] C Perkins and P Bhagwat, “Highly Dynamic Distance Destination Sequenced Distance Vector Routing (DSDV) for Mobile Computers”. Computer Communication, pp.234-244. October 1994.

[14] A.I. Alshabtat, L. Dong, J. Li, F. Yang, “Low latency routing algorithm for unmanned aerial vehicles ad-hoc networks”, International Journal of Electrical and Computer Engineering 6 (1), 2010, pp. 48–54.

[15] Johnson, D.B., Maltz, D. A.,“Dynamic source routing in ad hoc wireless networks”. In: Mobile Computing, Chapter 5, 1996, pp. 153–181.

[16] T.X. Brown, B Argrow, C Dixon, S Doshi, RG Thekkekunel, D Henkel,“Ad hoc UAV ground network”(AUGNet).In:3rd AIAA Unmanned UnlimitedTechnical Conference, 2004, pp. 29–39.

[17] S Murthy, JJ Garcia-Luna-Aceves,“An efficient routing protocol for wireless networks”. In: ACM Mobile Networks and Applications, 1996, pp. 183–197.

[18] JH Forsmann, RE Hiromoto and J Svoboda,“A time-slotted on-demand routing protocol for mobile ad hoc unmanned vehicle systems”. InDefense and Security Symposium. International Society for Optics and Photonics. pp. 65611P-65611P, April 2007.

[19] C Tracy, B Jeff and V Davies, “A survey of Mobility Models for Ad Hoc Network”, Research ‖ , http://toilers.mines.edu last accessed on (February 15, 2007).

[20] K Kumari, S Maakar, B sah, “A Brief Survey of Mobility Model for FANET”, National Conference on Innovative Trends in Computer Science Engineering held at BRCMCET4th ,April 2015.

[21] W Lin-Zhu, F Ya-qin, S Min, "Performance comparison of two routing protocols for ad hoc networks." In Information Engineering, 2009. ICIE'09. WASE International Conference on, vol. 1. IEEE.

[22] V.Tolety. Load reduction in ad hoc networks using mobile servers. Master's thesis, Colorado School of Mines, 1999.

[23] K Kumari, S Maakar, B sah, "A Survey: Different Mobility Model for FANET", International Journal of Advanced Research in Computer Science and Software Engineering, June 2015.

[24] I Bekmezci, M Ermis, S Kaplan, "Connected multi UAV task planning for flying ad hoc networks". In Communications and Networking (BlackSeaCom),IEEE International Black Sea Conference, 2014, pp. 28-32.

[25] O Bouachir, A Abrassart, F Garcia,"A Mobility Model For UAV Ad hoc Network". ICUAS 2014, International Conference on Unmanned Aircraft Systems, Orlando, United States. pp 383-388, May 2014

A Robust Audio Watermarking Technique Operates in MDCT Domain based on Perceptual Measures

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***Abstract*—the review presents a digital audio watermarking technique operating in the frequency domain with two variants. This technique uses the Modified Discrete Cosine Transform (MDCT) to move to the frequency domain. To ensure more inaudibility, we exploited the proprieties of the psychoacoustic model 1 (PMH1) of MPEG1 encoder layer I in the first variant and those of psychoacoustic model 2 (PMH2) of MPEG1 encoder Layer III in the second alternative to search the places for insertion of the watermark. In both variants of the technique, the bits of the mark will be duplicated to increase the capacity of insertion then inserted into the least significant bit (LSB). For more reliability in the detection phase, we use an error correction code (Hamming) on the mark.**

Next, to analyze the performance of the proposed technique, we perform two comparative studies. In the first, we compare the proposed digital audio watermarking technique with her two variants and those achieved by Luigi Rosa and Rolf Brigola, 'which we download the M-files of each'. The technique developed by Luigi Rosa operates in the frequency domain but using the Discrete Cosine Transform (DCT) as transformation and that proposed by Rolf Brigola uses the Fast Fourier Transform (FFT). We studied the robustness of each technique against different types of attacks such as compression / decompression MP3, stirmark audio attack and we evaluated the inaudibility by using an objective approach by calculating the SNR and the ODG notes given by PEAQ. The robustness of this technique is shown against different types of attacks. In the second, we prove the contribution of the proposed technique by comparing the payload data, imperceptibility and robustness against attack MP3 with others existing techniques in the literature.

Keywords—digital audio watermarking; Hamming; LSB; psychoacoustic model1, 2; MDCT; DCT; FFT; SNR; ODG

I. INTRODUCTION

Internet development and more generally the new means of communication oriented Western society into an era where digital takes a place increasingly important: Gradually digital cameras supplanting the old chemical film, DVD players replace VCRs as the Compact Discs were able to do with the disc vinyl.

In fact, digital copies are perfect now, whereas before each generation of analogical copies introduced further degradation. In addition, peer to peer networks for exchanging files can easily exchange huge volumes of multimedia data. Thus, providers of multimedia content quickly saw their sales fall significantly. They are very attentive to some new technology that will improve the digital rights management and prevent illegal redistribution of multimedia content.

However, digital technologies pose serious problems since it is easy to copy and deal with the computer digital documents. As a result, copyright is becoming increasingly unsafe and which leads to an illegal redistribution of data.

Hence the value of digital watermarking [1] as an effective solution to these problems and with the basic idea is to insert it in the digital document (image, sound, video ...) a signature so robust and imperceptible.

The watermark W is inserted into the multimedia document M to obtain watermarked document M' by application of an insert function I of the mark and using a key C. The marked media M' can undergo transformations T. The resulting document M" through an extraction function D for the detection of the brand W' (which may be identical or not to mark the initial W) or to confirm the presence or absence of the brand.

- *Robustness:* Being robust is equivalent to finding the inserted mark regardless of the changes that may infect the watermarked object. These changes are due to several types of treatments (attacks), as the passage in an analog channel resampling (print / SCANNING eg for images) compression with loss of information (such as JPEG compression [2] for images or MP3 to sounds), nonlinear distortions, additive channel noise ... However, the most marking system resist these simple transformations, but does not support the combination of them. Hence the idea of the malicious attack "StirMark" for the audio and image
- *Insertion capacity (Ratio):* This characteristic is important; it is the quantity of information that can be inserted into the original message. It is also called the payload or capacity of watermarking. Generally, in watermarking, we not fit voluminous raw data but enough useful information.
- *Imperceptibility:* In order to the mark is not easily crushed it should be imperceptible to any human: pirates, client, web visitors.... Too little perceptible mark is not robust and, worse, could be wrongly detected.

II. State of the Art

This section presents some digital audio watermarking techniques that exist in the literature.

- Boney, Tewfik and Hamdy [3] proposed a watermarking technique operates in the temporal domain. In this watermarking method, they build a brand that cans cryptographies. The psychoacoustic model calculates the masking threshold for the audio signal and filtering the brand. Then, the mark is added in the time domain to the audio signal.
- Fallahpour and Megias [4] proposed a technique using FFT transform. It involves inserting a stream of bits (secret bits) in selected FFT magnitudes while selecting the following parameters: scale factor, frequency band and frame size. Then, the FFT samples in the selected frequency band are divided into frames of size d. Then, they calculate the linear regression of FFT magnitudes for each frame. Thereafter, they calculate the average of the regression of magnitudes of the FFT samples in each frame. Finally, by means of a function f defined in [3] they insert the secret bits. The watermarked audio signal in the time domain is obtained by applying an inverse FFT. The extraction of the mark is performed using the FFT and the previously selected parameters and transmitted to the decoder in a secure manner.
- Fallahpour and Megias [29] propose another watermarking technique in the frequency domain using FFT transform. This technique consists integrate data and extract them in a bit-exact manner by modifying some values of the amplitudes of the FFT spectrum. The main idea is to divide the FFT spectrum in short frame and modify the amplitude of the selected samples using Fibonacci numbers that allow changing the frequency samples adaptively.
- S.T. Chen, H.N. Huang and C.J. Chen [5] proposed an adaptive audio watermarking method using the wavelet-based entropy (WBE). After the application of discrete wavelet transforms (DWT), they convert low-frequency coefficients into the WBE domain. Thereafter, they calculate the average values of each audio as well as derivation of some essential properties of WBE. From WBE and DWT coefficients, they calculate a characteristic curve. The basis of the integration process lies on the approximately invariant property demonstrated from the mean of each audio and the characteristic curve. In the extraction process, they use only values of the WBE.

A. *Objectives*

The main objective of this work is to develop a new watermarking system with high performance in which we seek to optimize these attributes:

- Increase the insertion capacity defined by the total number of bit to be inserted in the audio signal.
- The effect of this important capacity on the resulting signal. We seek to find a solution with which we get a tattooed signal faithful to the original.
- We estimate also reduce the complexity of the algorithms of both insertion and detection process.
- We aim to develop a technique that can resist against the maximum number of attacks and manipulations.

III. Proposed Technique

For after what we have presented above and after an extensive literature review [6, 3, 7, 8, 9, 10] led us to choose the frequency domain as an area of insertion of the mark point of view robustness and inaudibility hence the idea of using MDCT [19] to the time-frequency mapping [11, 3, 8]. On the other hand, MDCT allows a finer frequency resolution and studies the effects of edges. In addition, temporal methods based on LSB provide good results in terms of inaudibility and integration capability, but in part against, they introduce the brand damage which reduces the robustness factor. For these reasons, we applied this method (LSB method), but in the frequency domain. Parallel with this spectro-temporal processing, substitutive methods offer the possibility of using an error correcting code to reduce the error rate. For this, we have added to the proposed technique an error correcting code: Hamming code.

To reduce the audibility of the brand when inserting the bits of the brand, we have exploited the properties of the psychoacoustic model 1for variant 1 and the psychoacoustic model 2for variant 2 of the MPEG standard in the search for insertions positions. In the final step, we duplicated the bits of the brand to enhance the robustness of the proposed method.

- MDCT:

The MDCT is a lapped transform that allows doing the time-frequency mapping. It's widely used in audio processing and in particular it is used during MPEG audio compression procedure [12].

The MDCT coefficients are separated into “Low-Frequency” part and “High-Frequency” part. The major interest of this transform is that the coefficients are real and there are also robust to manipulations changing their values.

The general expression of the MDCT applied on blocks of N samples is as follows:

$$X(f) = \frac{2}{\sqrt{N}} \sum_{n=0}^{N-1} x(n) w_a(n) \cos\left(\frac{2\pi}{N}(n+n_0)\left(f+\frac{1}{2}\right)\right) \quad (1)$$

With:

- $x(n)$: Frame of N time domain sample.
- $f \epsilon \left[0, \frac{N}{2} - 1\right]$
- $n_0 = \frac{1}{2} + \frac{N}{4}$
- w_a : The analysis window with duration N.

The expression of the inverse transform (IMDCT) is:

$$y(n) = w_s(n)\frac{2}{\sqrt{N}}\sum_{f=0}^{\frac{N}{2}-1} X(f)\cos(\frac{2\pi}{N}(n+n_0)(f+\frac{1}{2})) \quad (2)$$

With:

- $n \epsilon [0, N-1]$
- w_s : The synthesis window with duration N.

We note that the MDCT of N sample of the signal gives only N / 2 coefficients, so it's not an invertible transform.

However, by tacking a recovery of 50% between successive blocks and ensuring some conditions on the analysis and synthesis window we can achieve a perfect reconstruction of the time signal from unmodified MDCT coefficients.

A. Insetion of the mark: first variant of the technique

In this first version of the proposed watermarking technique we will integrate the psychoacoustic model 1 of the MPEG standard Layer I. In the following, we will explain in detail the different modules constituting the algorithm of the insertion process:

1) Original signal: The initial input signal is an audio file of format (.wav), stereo or mono, sampled with a sampling frequency Fs = 44.1 kHz.

2) Decomposition into blocks: To increase the insertion capacity (number of bits to be inserted), we proceeded to the block decomposition of the signal. After reading and verifying the original audio, we obtain a vector containing the time samples. If the latter is stereo, we transform it into a mono audio signal. The final signal will be broken down into blocks of 1024 samples each. Thus we obtain a matrix ‹‹ block (i,k)›› of 1024 rows and NB_block columns: i=1…1024 and k=1…NB_block =length(original_audio)/1024. We can formulate this step by the following equation:

$$original\_audio = \sum_{k=1}^{NB\_block} Block(k) \quad (3)$$

3) MDCT: This version of the technique operates in the frequency domain. To make the time-frequency mapping, we applied the MDCT on each block of 1024 samples. The coefficients of the MDCT are separated into two bands: band of "low frequency" and band of "high frequency". The major interest of this transformation is that the coefficients are real and also robust to manipulations changing their values. The output of this module is a matrix block_MDCT containing the set of blocks of 1024 frequency samples obtained by the MDCT. By applying equation (1) we get for a block k:

$$block\_MDCT(:,k) = MDCT(Block(:,k)) \quad (4)$$

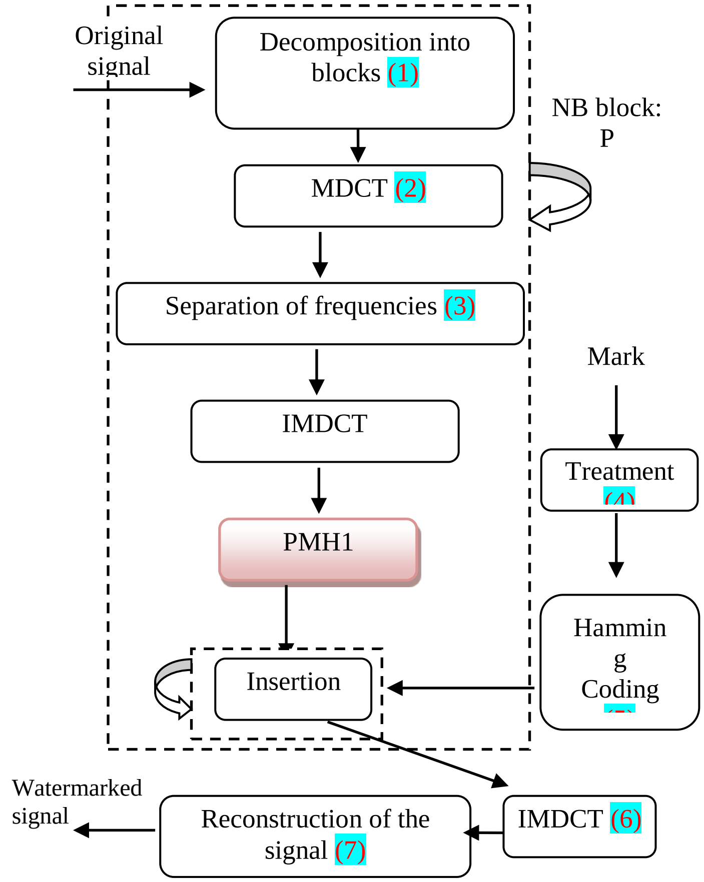

Fig. 1. Insertion schema of the mark: version 1

4) Separation of frequencies: The purpose of this module is to limit the low frequency band where we will perform the insertion. The matrix block_MDCT forms the input of this module. We take every block that is to say each column of the matrix block_MDCT, and we set the low-frequency band. The choice to integrate watermarking bits in the low frequency band due to the fact that the latter is much less sensitive to the attacks applied on the watermarked signal that the high frequency band which will be changed and even eliminated (especially compression / MP3 decompression).

We obtain at the end of this step a matrix low_freq containing all the low frequencies for each block k.

5) IMDCT: As the psychoacoustic model of the MPEG 1 standard operates on temporal samples. So it is necessary to go back to the time domain. By applying equation (2) of the IMDCT on each column of the matrix low_freq (which correspond to the low frequency band of each block k), we get the matrix low_freq_IMDCT of i = 1 … .512 rows and k = 1 … .NB_block columns:

$$low\_freq\_IMDCT(k) = IMDCT(low\_freq(k)) \quad (5)$$

6) PMH1: This module consists to look for insertion positions watermarking bits using a human psycho acoustic model. It takes as input the columns of the matrix low_freq_IMDCT formed by temporal samples. We will inject the bits of the brand in the components located under the masking curve calculated by the PMH1. And since, below this curve no modification is noticeable; this guarantees a good criterion of inaudibility of the brand. The application of the PMH1 and calculates of the masking curve will be for each block of 512 temporal samples of the low frequency band. We will have at the end of this step X insertion positions where we will substitute watermarking bits. The masking curve for a block k (one column of the matrix low_freq_IMDCT) is given by:

$$masking\_curve(k) = PMH1(low\_freq\_IMDCT(k)) \tag{6}$$

$and;$

$$X\_position(k) = components\_below\_masking\_curve(k) \tag{7}$$

7) Treatment: The process of inserting of the proposed technique can integrate any type of mark (text, image, and beep). But next in the experiments and evaluation of this version of the technique, we tried with text mark (string). Parallel to the above steps, we will then binarizing ASCII codes. The length of the mark (text) is chosen multiple of 8. We then get after binarization and shaping of the brand a binary vector of length multiple of 8. This choice will then be useful to make a Hamming (12, 8) coding to each byte of the binary vector.

8) Hamming coding: Following the insertion, detection of signature and attacks or manipulations which may act on the watermarked audio signal, the inserted bits of the mark may be changed (inversion from 0 to 1 or 1 to 0). Therefore, to improve the mark detection we proceed to the coding of the binary vector obtained by the Hamming coding after the step of binarizing and shaping described above, to ensure bit correction if it's necessary.

9) Insertion: The general principle of insertion of the brand can be described as follows: For each block k, the current bit of the message (obtained from the previous step of the coded binary vector) is substituted with the least significant bit "LSB" of the sample X_Position (i) searched in the step (6). The watermarking technique is substitutive and the insertion is performed on all blocks by inserting N times each bit of the mark (duplication of the mark bits). N is calculated based on the number of the components which are below the masking curve and the mark size.

$$N = \frac{\sum_{k=1}^{NB_{Block}} X\_position(k)}{length\_mark} \tag{8}$$

We get at the end of this step the signal block_wat "watermarked block".

10)IMDCT: After the substitutive insertion of the watermarking bits in each block, we get NB_Block watermarked in the frequency domain. In order to reconstruct the final watermarked audio signal, we need to move to the time domain.

11)For this reason, we will apply the IMDCT but this time on blocks of length 1024 samples. We obtain at the end of this step a matrix block_wat_tim containing time blocks watermarked and of dimension i = 1...1024 lines and k = 1...NB_block columns. So for a block k of size 1024, we get:

$$block\_wat\_tim(k) = IMDCT\ (block\_wat(k)) \tag{9}$$

12)Reconstruction of the signal: This module is the final step of the insertion process. Given all the time NB block watermarked block_wat_tim obtained by applying the IMDCT, we join them to form the watermarked audio signal audio_wat mono of format ".wav", sampled with the same frequency sampling the original audio signal Fs = 44.1 kHz.

B. Detection of the mark: first variant of the technique

This section details the different fundamental steps of the detection process. In the proposed technique, the detection is performed inversely to the insertion. One of the merits of this first variant of the proposed technique is that the detection is blind and does not require the original audio signal for detecting the mark. The set of parameters required when detecting and must be secured by the tattooist are:

- The number N of duplication that we can insert a bit.
- The list of positions of the components located under the masking curve sought by the human psycho acoustic model 1 in the insertion phase.

In the following, we will detail the various modules constituting the detection algorithm.

1) Decomposition into blocks: First, we decompose into blocks of 1024 samples the watermarked audio signal obtained after insertion of the brand.

2) MDCT: The time frequency mapping is performed by applying the MDCT transform equation (1).

3) Detection, Elimination of duplication, Hamming decoding: Then from the secret key, which is an array containing the positions of the components that are below the masking curve sought by the psychoacoustic model 1 in the insertion process, we can detect the bits of the brand inserted in the samples corresponding to these positions. As a result, we will then obtain a binary vector containing the bits corresponding to the coded signature. The size of the detected mark is multiple of 12. Subsequently and after the elimination of duplication, we decode the signature obtained by Hamming decoding, after which the detection and correction of one error, if it exists, it will extract the 8 data bits corrected of each 12 data bits, to find only a corrected code signature multiple of 8.

4) Formatting the mark: Finally, we proceed to format the brand to form the corresponding mark already inserted.

Figure 2 conceptualize the different steps necessary for the detection procedure of the mark.

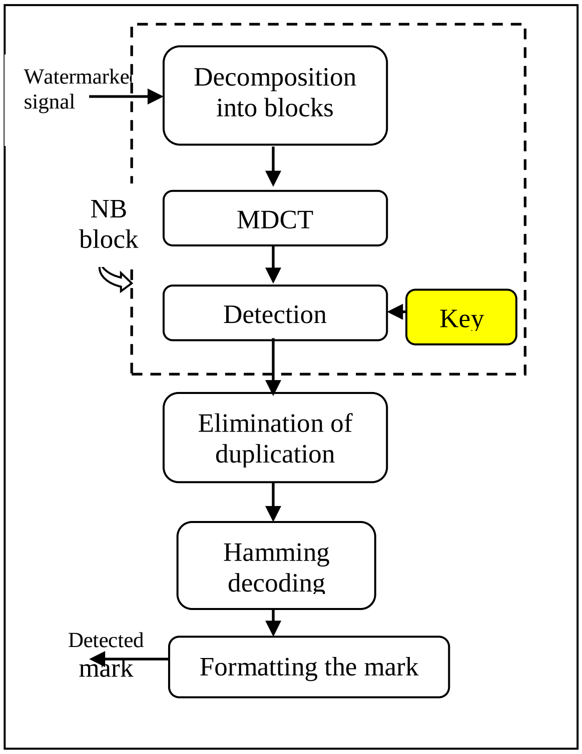

Fig. 2. Detection schema of the mark: version 1

C. Insetion of the mark: second variant of the technique

In this second variant of the proposed watermarking technique, we will integrate the psychoacoustic model 2 of MPEG 1 layer III to exploit its properties in search of the insertion positions of the mark. This version operates in the frequency domain. The time-frequency mapping is performed using the MDCT transform applied to sub-blocks of the original audio signal (.wav). The steps of (1) to (7) are the same as of the first version of the technique. After the decomposition into blocks of the original audio signal and steps (2) and (3) we will look for the insertion positions of the watermark bits.

To search for the places of insertion them less audible to the human ear, we will apply the psychoacoustic model 2 (PMH2) of the MPEG standard on the temporal samples of each sub-block of 1024 samples. This model will calculate for each block a final threshold of energy hearing thr_w . Watermarking bits will be injected into the components located under the thr_w. The number and the positions of these components differ from one block to another and from a signal to the other (dynamic). This makes the number of bits to be inserted is not the same for all the blocks and will offer a good compromise between robustness and inaudibility.

After steps (4) and (5), each bit of the coded mark is duplicated N times where N is calculated based on number of components that are below the final threshold of energy hearing and the size of the brand.

$$N = \frac{sum\left(components_{below_{final-threhold}}\right)}{size_{brand}} \quad (10)$$

Next, we will make a substitutive insertion of each bit of the mark in the least significant bit (LSB) of the components searched by the PMH2. All the previous steps will be repeated NB block times (number of blocks in the audio signal) and the insertion is done on all the blocks of the audio signal. Thereafter, we apply the IMDCT on the frequency watermarked blocks of 1024 samples to obtain watermarked blocks in the time domain. The last step is to reconstruct the watermarked audio signal.

This approach offers a good compromise between robustness and inaudibility.

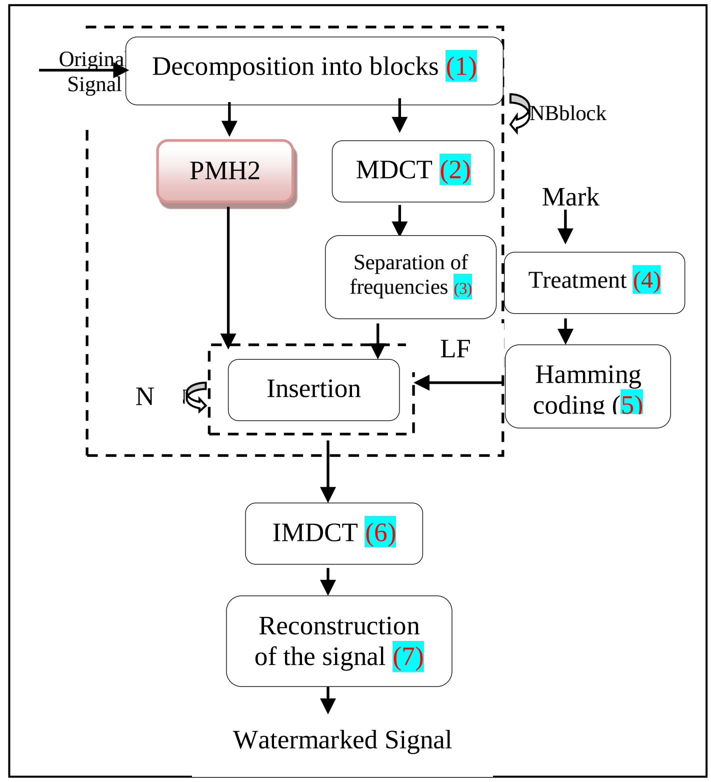

Fig. 3. Insertion schema of the mark: version 2

D. Detection of the mark: second variant of the technique

All stages forming the detection scheme for this variant are the same as for the detection in the first version (Fig. 2), except that the key will change. In this version, it is the set of positions of the components which are below the final hearing of the energy generated by the model 2 for each block. At the end of this process, we obtain the brand inserted into the original signal.

IV. Comparative Study 1: Comparison with the Techniques of Rosa and Brigola

In this section, we will present the results of the comparative study between the proposed technique with her two variants and two other techniques from the literature. First, we present the technique proposed by Luigi Rosa, then the one suggested by Rolf Brigola.

A. Technique proposed by Luigi Rosa

This technique is based on the algorithm of A. Piva whose general principle is:

- The watermarking method operates in the frequency domain using the DCT (Discrete Cosine Transform).
- L.Rosa will insert a random sequence of real numbers in the selected coefficients of the DCT.
- To ensure more inaudibility of the mark, the places of insertion are selected using a psychoacoustic model.
- The detection scheme is semi-private since it not used the original document and only gives an answer on the presence of the brand:
  - 0: could not detect the mark.
  - 1: could detect the mark.

1) Insertion scheme of the mark:

In the beginning, the author divided the original signal into blocks of N samples. Time-frequency mapping is made by the DCT transform. Then, he selects the k among the N coefficients obtained by the DCT, and he applies a psychoacoustic model on these samples to look for the places of insertion. Thereafter, he proceeds to an additive insertion of the brand.

2) Detection scheme of the mark:

The detection scheme of the mark in this technique is semi-private. The first step of detection process is to decompose the watermarked audio signal into blocks of size N. Thereafter, the author applies the DCT to move to the frequency domain. Then, he selected the watermarked coefficients to generate the vector T'. The comparison between T' and the mark itself gives an answer about the presence of the mark (it was possible to detect the brand or not).

B. Technique proposed by Rolf Brigola

1) Insertion scheme of the mark:

First, R. Brigola makes silence treatment. He jumped 31 samples from the beginning of the original signal. Later, he decomposed the signal into blocks of 8820 samples. And as the scheme of watermarking operates in the frequency domain, he applied the FFT transform to each block to do the mapping. The insertion of bits of the brand is done in the peaks of the FFT corresponding to 5 Hz, which belong to the low frequency band (under the scope of the audible spectrum). For this, he looks for each block all the peaks corresponding to 5 Hz. Thereafter, he applies the IFFT transform on the frequency watermarked blocks of 8820 samples to obtain watermarked blocks in the time domain.

The last step is to reconstruct the watermarked audio signal. This technique is performed on stereo audio. Therefore, all previous steps will be made on each channel.

2) Detection scheme of the mark

The detection scheme of the brand is the reverse of that of insertion. Except that, we need the watermarked audio signal and the inserted mark to verify the size of the detected mark. As in the insertion process, we start with a treatment of the silence for the watermarked audio. After decomposition into blocks of 8820 samples, the author applies the FFT transform to move to the frequency domain.

Thereafter, he looks for all positions where it has been inserted the mark to detect the bits of the brand previously injected. For the detection, it needs the brand already inserted to check the size of the detected mark. The final step is to format the detected bits of the mark.

C. Experimental results

In the following, we present various experimental results obtained in this study.

For this reason, we download the M-files of the previous two techniques (that of Brigola and Rosa). We tested the robustness and the inaudibility of the three techniques on an experimental corpus containing 12 recordings. The latter signals are sampled at CD quality (at a sampling frequency Fe = 44.1 kHz), duration 20s on average and different style: symphony orchestras, spoken voices (male and female), jazz, rock, singing voice… We inserted the text mark "audiowatermarking" of length 136 bits and after the hamming coding its length reaches 204 bits (after that each bit will be duplicated N times).

1) Inaudibility:

a) Objective evaluation of sound quality by the PEAQ algorithm:

For the objective evaluation we used the PEAQ algorithm [18] gives a note of ODG (Objective Difference Grade).

This algorithm compares the original signal and the watermarked signal and assigns a score between 0 and -4. If the note ODG = 0 means no degradation, if we get an ODG score that varies between -0.1 and -1 this means that the degradation is perceptible but not annoying, for an ODG score that varies between -1.1 and -2 this means that the degradation is slightly annoying, if the ODG score obtained varies between -2.1 and -3 this means that the degradation is annoying, finally, if the ODG score obtained is in the interval [-3, 1; -4] the distortion is very annoying.

The following table shows the meanings of each note.

TABLE I. SIGNIFICATION OF ODG NOTES

Signification	ODG
Imperceptible	0,0
Perceptible but not annoying	-0,1 to -1
Slightly annoying	-1,1 to -2
Annoying	-2,1 to -3
Very annoying	-3,1 to -4

The results will be displayed in the figure 4. The vertical axis represents the value of the note ODG given by PEAQ. According to the results in figure 4, we note that the proposed technique and more precisely the second variant of the proposed technique gives the most interesting results point of view inaudibility. The values given by PEAQ ranged from 0 (imperceptible) for the two variants of the proposed technique to extracts jazz, Svega, gainsbourg, feelgood ,LoopyMusic and to -0.81 and -0,75 respectively for variant 1 and variant 2 (perceptible but not annoying) to Beethoven. For the two other techniques, we note that for the two extracts "jazz, LoopyMusic" we find a note ODG equal to - 1.98, -1.90 for that of L.Rosa and -0.64, - 0.93 for that of R. Brigola.

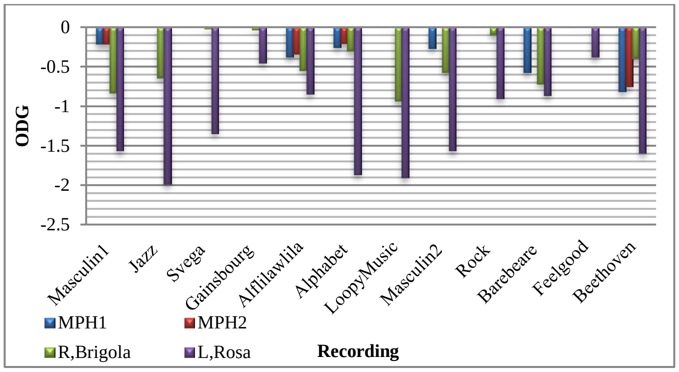

Fig. 4. Graphical representation of the absolute values of the ODG notes

b) Evaluation of sound quality by calculating the SNR

Another way to evaluate the sound quality is to compute the SNR (signal-to-noise ration). It is a measure that calculates the similarity between the original audio and the watermarked audio. The results for the three techniques are shown in the following figure. We also note that the SNR shows more the inaudibility guaranteed by the performed technique. Based on the results shown in Figure 5, we notice that the new proposed technique with its two variants provides a very important criterion of inaudibility. We also points out that the variant using the psychoacoustic model 2 gives the best results.

For example, we remark that the range of values produced by the proposed technique, variant 2, varies between 47, 89 dB et 62, 96 dB. For variant 1, the range of values varie between 46, 26 dB et 58, 55 dB. While for the technique of L.Rosa this range varies between 25,32 db and 27 db. In addition, the minimum value of the SNR obtained by the technique of R.Brigiola is 20dB while the maximum value is 35,8 dB.

Consider the example of the recording (feelgood.wav), we have reached a value of 62.96 dB with the developed technique, variant 2, 57, 34 dB with variant 1 and a value of 35, 87 dB for the one by R. Brigola and 26, 07 dB for the technique of L. Rosa, which proves again the inaudible character of the variant 2 of the developed technique.

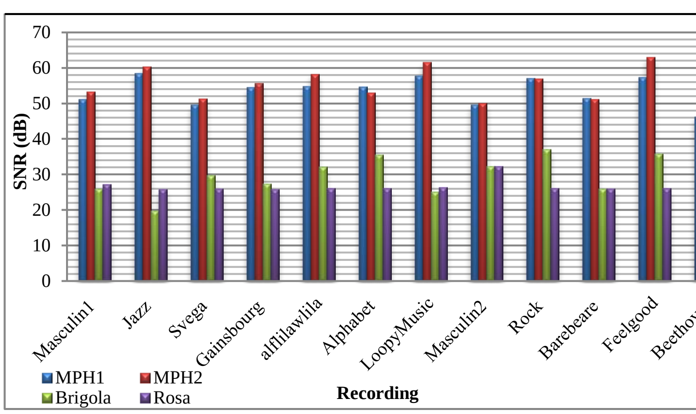

Fig. 5. Graphical representation of the values of the SNR

2) Robustness Tests:

In this section we give the results of robustness tests of the three techniques that we have made against some forms of attack. Disturbances considered in evaluating watermarking systems are realized using the tool "Stirmark Audio" and the encoder MPEG1 "lame.exe" to do the compression / decompression MP3 with three different rates 128kbps, 96kbps and 64kbps.

a) Against attacks stirmark audio

Stirmark Audio [19, 20] is a standard used by researchers in watermarking. This is an executable tool proposed by Lang [21] which tends to become a benchmark for evaluation procedure of the robustness of audio watermarking. This tool generates all versions of a degraded audio signal by various disturbances, both legal and illegal. Stirmark Audio" offers different types of attacks [22]: addition of an echo "echo", the application of a high pass "filter "rc_highpass", the application of a low pass filter "rc_lowpass" smoothing "smooth" , addbrumm, ...

The results of robustness against these attacks are shown in the figure below. On the abscissa are mentioned types of attacks "stirmark audio" used, and the on ordinate is mentioned, with each attack, the number of records that who resisted this type of attacks.

Looking at the figure, we see that the developed technique with the two variants gives the same results. It's robust against a large number of attacks and for all records. It's more robust than the two other techniques against the most attacks. For example, the number of audio robust against attacks compressor, fft_invert, rc_highpass, fft_hlpass, flippsample, fft_real_reverse, addbrumm, addsinus, … is12 recordings. For the technique of L. Rosa we find that it give poor results in terms robustness. This technique is not robust against attacks addsinus and fft_real_reverse and that for all records. We also note that the technique of R. Brigola is robust against attack "amplify" that means the increase or diminution of the amplitude of the audio signal, while the two others did not. Finally, we notice that the three techniques are not robust against attacks echo, copysample, resampling and smooth as they significantly degrade the watermarked audio signal.

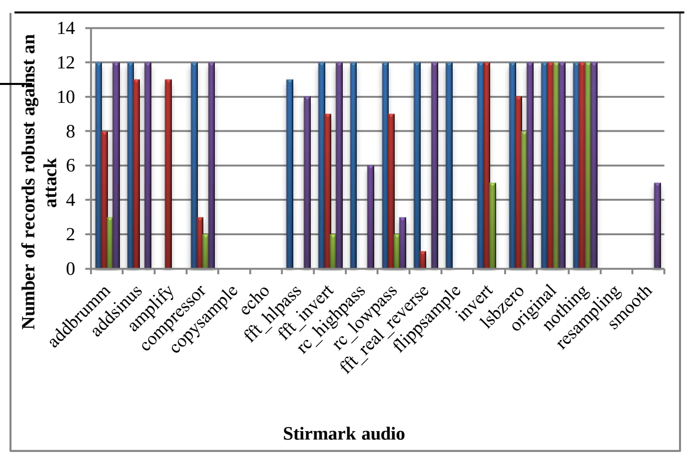

Fig. 6. Detection results after applying stirmark audio attacks

b) Against compression/decompression MP3 attack

We will perform the compression / decompression MP3 with "lame.exe" at different compression rates: 128 kbit / s, 96 kbit / s and 64 kbit / s. Test results are displayed in the following figure:

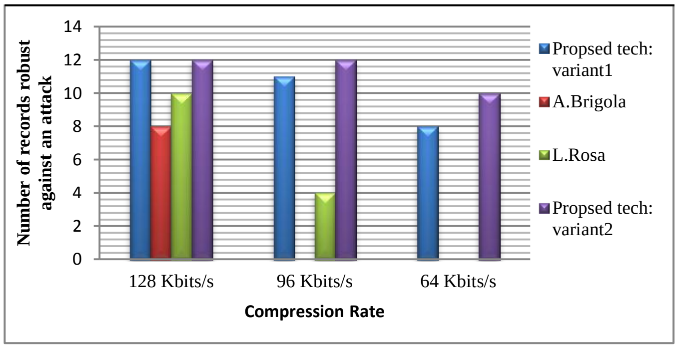

Fig. 7. Detection results after applying stirmark audio attacks

From the results shown in Figure 7 we note that:

- For all records, the variant 1 of the proposed technique is always robust against the attack of compression / decompression at a rate of 128 Kbits / s. This robustness decreases to a rate of 96 Kbits / s to become increasingly weak to 64 Kbits / s but still very interesting (8 records robust among 12).
- For all records, the variant 2 of the proposed technique is always robust against the attack at a rate of 128 Kbit / s and 96 Kbits / s. At a rate of 64 Kbits/ s, the robustness decreases slightly but still very important (10 records robust among 12). These results show the interest of this second variant in terms robustness.
- For the other two techniques, we find that this robustness is low especially for a rate of 96 and 64 Kbit / s. For example the technique of A. Brigola does not resisted against this attack for any records with the two rates of compression / decompression: 96Kbit / s and 64 Kbit / s. While that of L. Rosa has 4 records that have resisted against this type of attack with the rate 96 kbit / s and 0 record with the rate 64Kbit / s.

V. Comparative Study 2: Comparison with Others Existing Techniques

To highlight the results, we will compare in this section the proposed technique with others techniques existing in the literature. Before presenting the comparison, we will define the payload.

The data payload represents the number of bits that are embedded into the audio signal within a unit of time and is measured in the unit of bps (bits per second).

Suppose that the length of the audio signal is S seconds, and the number of bits to be inserted in the signal is K bits. So the data payload D is defined as following:

$$D = \frac{K}{S} \ (bps) \tag{11}$$

We choose to present the results above a payload data between 72.85 bps and 185.45 bps (depending on length in seconds of tests extracts) and we can even insert more.

This performance is superior to others audio watermarking existing algorithms.

In the table below we show the contribution of the proposed technique in terms of inaudibility of the brand. We will give the average ODG values obtained for the watermarking systems.

TABLE II. Comparison of ODG Average Values

References	Payload (bps)	ODG average values
Proposed	72,85-185,45	-0,2
Khaldi & al.[23]	46,9-50,3	-0,5
Baras & Moreau [24]	83	-0,4

TABLE III. Comparison of Methods Against MP3 Attacks Sorted by Attempted Payload

Reference	Payload (bps)	Robustness to MP3 (Kbps)
Proposed	72,85-185,45	64
Khaldi & al.[23]	46,9-50,3	32
Lie & Chang [25]	43	80
Yeo & Kim [26]	10	96
Thahibana & al.[27]	8,5	96
Xiang & al. [28]	2	64

We can conclude that after the results presented in the two tables II and III that the proposed technique presents interesting performance, point of view imperceptibility of the brand (ODG = -0.2), important payload data (185.45 bps) and robustness against MP3 attack at a rate equal to 64 Kbps. Despite the fact that the robustness against MP3 attack at a compression ratio equal to 64 Kbps remains interesting, we note that the technique proposed in [23] guarantee robustness at a rate of 32 Kbps, which is still interesting and a challenge to reach.

VI. Contribution

We will mention in the following main benefits guaranteed by the two versions of the proposed technique:

- Both versions of the technique provide a very high capacity of insertion. The insertion is done in each block on the whole of the watermarked signal. In addition, each bit of watermarking message is inserted N times and at the end of the insertion process we will have a very important total inserted bits equal to N * number of bit of the message after Hamming coding.
- The number of duplication N is variable (varies from one signal to another). This dynamically calculated according to the message size and the number of insertion positions found using one of the two models used. This provides additional security for the inserted message other than the Hamming coding.
- Despite this important capability of insertion, we have not altered without applying attacks, the quality of the

audio signal and we got a watermarked file faithful to the original file.

- The detection is perfectly blind and does not require a lot of additional data (only a secret key and the number of duplication N) for extracting the injected mark. This latter provides a gain in terms of execution time of the detection process (fast algorithm).
- The use of MDCT allows a finer frequency resolution and treats the block effects that cause noticeable distortion.

VII. CONCLUSION

In this paper, we proposed a robust watermarking audio technique operating in the frequency domain. The time-frequency mapping is done by an MDCT transform applied on blocks of 1024 samples each. This transformation provides a separation between the high frequencies and low frequencies.

The inaudibility of the brand is favored by the insertion of bits of the brand in the LSB of the components looked for by the psychoacoustic model 1 of the MPEG standard in the first variant and the psychoacoustic model 2 of the MPEG standard in the second variant .

Duplication of bits of the mark across the signal for the two variants increases the robustness of the technique against a large number of attacks and manipulations, and also allows for a high embedding capacity.

This important capacity does not alter the sound quality of audio signals. Moreover, the original brand is well identified during the detection phase. This detection is improved by using Hamming coding.

In addition, we presented two detailed studies covering the performed technique and others exist in the literature. The results show the performance of the proposed technique point of view robustness, imperceptibility and capacity of insertion (scheme of the developed technique has higher payload).

As perspective, we look to enlarge the comparative study and to use other measures to test the inaudibility of the mark in the insertion phase and in order to best enhance the robustness criterion and to better show the performance of the technique carried out against the attacks we plan to calculate the bit error rate in the detection and after application of a different types of attacks.

REFERENCES

[1]. W. Bender, D. Gruhl, N. Morimoto, and A. Lu.:'Techniques for data hiding'. IBM Systems Journal, vol. 35, pp. 313–336, 1996.

[2]. M.W. Marcellin1, J Michael. Gormish, A. Bilgin, M. P. Boliek, "An Overview of JPEG-2000", Proc. of IEEE Data Compression Conference, pages 523-541, 2000.

[3]. L. Boney, A.H Tewfik, K.N. Hamdy, "Digital Watermarks for Audio Signals" , IEEE Int. Conf. on Multimedia Computing and Systems June 17-23, Hiroshima, Japan, pages 473-480, 1996.

[4]. M. Fallahpour and D Magias, "High capacity robust audio watermarking scheme based on FFT and linear regression", International Journal on Innovative Computing Information and Control:Vol. 8, Issue 4, 2012.

[5]. Shuo-Tsung Chen, Huang-Nan Huang1 and Chur-Jen Chen, "Adaptive Audio Watermarking via the Optimization Point of View on the Wavelet-Based Entropy", Digital Signal Processing, Volume 23, Issue 3, Pages 971–980, May 2013.

[6]. C. BARAS. : "Tatouage informé de signaux audio numériques". PhD Thesis, Ecole Nationale Supérieure des Télécommunications, 2005.

[7]. J. Pinel, L. Girin and C. Baras.: ' Une technique de tatouage haute capacité pour signaux musicaux auformat CD-audio'. 10ème congrès français d'acoustique. Lyon , Avril 2010, pages 12-16.

[8]. M. CHARFEDDINE, M. EL'ARBI and C. BEN AMAR. :' A blind audio watermarking scheme based on Neural Network and Psychoacoustic Model with Error correcting code in Wavelet Domain '. ISCCSP. Malta, 2008, pages 12-14.

[9]. D. labarre. :' Exploitation de la cyclostationnarité pour le tatouage des signaux audio (watermarking)'. Diplôme d'Etudes Approfondies (DEA), Ecole doctorale des sciences physiques et de l'ingénieur de l'université Bordeaux I, 2001.

[10]. N. Cvejic and T.Seppanen.:'Robust Audio Watermarking in Wavelet Domain Using Frequency Hopping and Patchwork Method'. Proceedings of the 3rd International Symposition on Image and Signal Processing and analysis, 2003.

[11]. J.Pinel, L.Girtin, C.Baras and M. Parvais. :' A hight-capacity watermarking technique for audio signals based on MDCT –domain quantization'. Proceedings of 20 th International Congress on Acoustic, ICA . Sydney, Australia, 2010, pages 23-27.

[12]. J.S. Jacaba . :'Audio Compression Using Modified Discrete Cosine Transform: The Mp3 Coding Standard'. A research paper submitted to the Department of Mathematics College of Science The University of the Philippines Diliman, Quezon City, 2001.

[13]. Norme internationale, ISO/CEI 11172-3, Technologies de l'information codage de l'image animée et du son associé pour les supports de stockage numérique jusqu'à environ 1,5 Mbit/s, partie 3 : Audio.

[14]. J. Prévost. :'Standards de compression audio-vidéo '. (CEA, GIP RENATER, Aristote), Mars 2007.

[15]. R.W.:'Hamming, error detecting and error correcting codes'. Bell Syst. Tech. , 1950, J. 26 (2), pages 147–160.

[16]. M. Bellaaj, K. Ouni. Comparative analysis of audio watermarking technique in MDCT domain with other references in spectral domain. In: 9th international multi-conference on systems, Signals and Devices, Chemnitz, 2012.

[17]. R. Brigola. A simple example on audio watermarking in the frquency domain. April 2010.

[18]. Union Internationale des Télécommunications (UIT): Recommandation B.S. 1387: Méthode de mesure objective de la qualité du son perçu, 2001.

[19]. F. Petitcolas, R. Anderson and M. Kuhn. :'Attacks on copyright marking systems'. Proceedings of the Second International Workshop on Information Hiding, 1998, volume 1525, pages 219-239.

[20]. Stirmark.http://www.petitcolas.net/fabien/watermarking/stirmark, accessed, june 2010.

[21]. http://www.iti.cs.uni-magdeburg.de/~alang/ , accessed june 2010.

[22]. A. Lang, J. Dittmann, R. Spring and C.Vielhauer. :' Audio Watermark Attacks: From Single to Profile Attacks'. 2005.

[23]. K. Khaldi and A.Boudraa, 'Audio Watermarking Via EMD'. Ieee Transactions on Audio, Speech, And Language Processing, Vol. 21, No. 3, pages 675-680, March 2013.

[24]. C. Baras and N. Moreau. 'Modulation CDMA informée dans un système de tatouage audio'.COmpression REpresentation des Signaux Audiovisuels (CORESA 2005), Nov 2005, Rennes, France. 2005.

[25]. W.-N. Lie and L.-C. Chang, "Robust and high-quality time-domain audio watermarking based on low frequency amplitude modification," IEEE Trans. Multimedia, vol. 8, no. 1, pp. 46–59, Feb. 2006.

[26]. I.-K. Yeo and H. J. Kim, "Modified patchwork algorithm: A novel audio watermarking scheme," IEEE Trans. Speech Audio Process., vol. 11, no. 4, pp. 381–386, Jul. 2003.

[27]. R. Tachibana, S. Shimizu, S. Kobayashi, and T. Nakamura, "An audio watermarking method using a two-dimensional pseudo-random array," Signal Process., vol. 82, no. 10, pp. 1455–1469, 200.

[28]. S. Xiang, H. J. Kim, and J. Huang, "Audio watermarking robust against time-scale modification and MP3 compression," Signal Process., vol. 88, no. 10, pp. 2372–2387, 2008.

[29]. Fallahpour, M., Megías, D. ,"Audio watermarking based on Fibonacci numbers ". IEEE Transactions on Audio Speech and Language Processing. Num. 8, Pag. 1273-1282. ISSN.1558-7916. DOI:10.1109/TASLP.2015.2430818, 2015.

Multi-Robot Path-Planning Problem for a Heavy Traffic Control Application: A Survey

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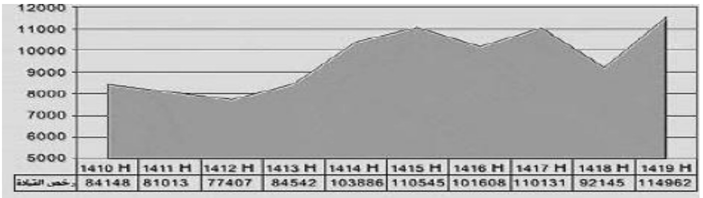
***Abstract*—This survey looked at the methods used to solve multi-autonomous vehicle path-planning for an application of heavy traffic control in cities. Formally, the problem consisted of a graph and a set of robots. Each robot has to reach its destination in the minimum time and number of movements, considering the obstacles and other robots' paths, hence, the problem is NP-hard. The study found that decoupled centralised approaches are the most relevant approaches for an autonomous vehicle path-planning problem for three reasons: (1) a city is a large environment and coupled centralised approaches scale weakly, (2) the overhead of a coupled decentralised approach to achieve the global optimal will affect the time and memory of the other robots, which is not important in a city configuration and (3) the coupled approaches suppose that the number of robots is defined before they start to find the paths and resolve collisions, while in a city, any car can start at any time and hence, each car should work individually and resolve collisions as they arise. In addition, the study reviewed four decoupled centralised techniques to solve the problem: multi-robot path-planning rapidly exploring random tree (MRRRT), push and swap (PAS), push and rotate (PAR) and the Bibox algorithm. The experiments showed that MRRRT is the best for exploring any search space and optimizing the solution. On the other hand, PAS, PAR and Bibox are better in terms of providing a complete solution for the problem and resolving collisions in significantly much less time, the analysis, however, shows that a wider class of solvable instances are excluded from PAS and PAR domain. In addition, Bibox solves a smaller class than the class solved by PAS and PAR in less time, in the worst case, and with a shorter path than PAS and PAR.**

Keywords—component; Heavy traffic control; Multi robots; Coupled Path Planning; Decoupled Path Planning; Collision Avoidance; Heuristics; RRT; Push and Swap; Push and Rotate; Bibox

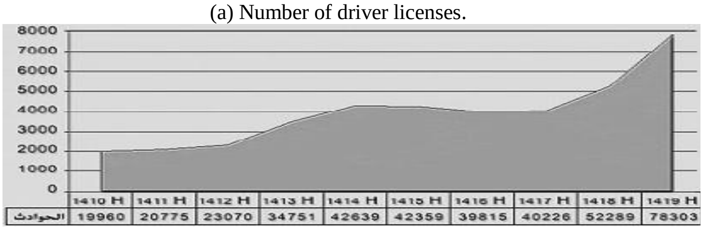
I. Introduction

As a city's population grows, the number of vehicle accidents increases (Fig.1), which may be caused by the personality of the driver, ignoring a disliked traffic regime, traffic congestion or variations in the speed of the vehicle. Therefore, moving vehicle control to a unified controlling system that optimises all vehicle preferences with respect to the surrounding traffic rules is one way to address part of the problem defined. Multi-robot path planning (MPP) is an abstraction of the problem of finding the complete optimal path from the start point to the target point for each robot with the minimum time and path length while considering the robotic constraints (obstacle avoidance) and inter-robotic constraints (collision avoidance). This survey studies the use of path-planning approaches for MPP for a heavy traffic control problem through a brief review of existing approaches. In addition, it explores four of the main decoupling path-planning approaches. The first is a well-known optimisation technique for single-robot path planning and three are exact methods proposed in the literature. Rapidly exploring random tree (RRT)[1] is an optimisation technique that uses an exploring tree to find the goal and enhance the path for a single robot. An extension to the technique has been implemented in this survey, to fit the MPP definition. Push and rotate (PAR)[2] is an extension of push and swap (PAS)[3]. Both are used to solve any problem with two unoccupied vertices. They are built on two primitives: (1) push on meeting a robot if it has lower priority and (2) swap with it if it has higher priority. Bibox[4] is used to solve any bi-connected graph with two unoccupied vertices. It decomposes the problem into two smaller handles and original cycle and solves them by iteratively moving and locking finished robots and shrinking the problem size. MPP is a relevant problem in a wide range of domains including; automatic packages inside a warehouse [5], automated guided vehicles [6], planetary exploration [7], robotics mining [8], and video games [9].

This paper is organized as follows; after this brief introduction, the multi robot path planning problem is defined from literature in section II. In Section III, the four selected methods is described briefly, followed by Section IV with a discussion of their theoretical analysis. In Section V, the experiments are introduced with a comparative analysis between the selected methods on different types of instances. Finally, conclusions and future work is presented in Section VI.



(a) Number of driver licenses.



(b)Number of accidents

Fig. 1. The latest statistics for Riyadh city between 1410 and 1419 A.H from https://www.moi.gov.sa/wps/portal/Home/sectors/publicsecurity/traffic/trafficriyadh

II. Problem Statment

Wilson [10] proposed an efficient decision procedure for the solvability of 15-puzzles, 14-pebble with one unoccupied vertex without considering the number of moves. Therefore his solution required exponentially many moves. Kornhauser et al. [11] generalized Wilson solution to solve Pebble Motion on Graph (PMG) problem with n-1 pebble in $O(n^3)$ for the number of moves. In that work, they defined PMG for number of pebble < vertices. Resultantly a move consists of transferring a pebble to an adjacent unoccupied vertex. In this scenario, the problem is to decide whether one arrangement of the pebbles is reachable within shortest sequence of moves from another or not. The problem defined by Kornhauser et al. can easily mapped to Multi-robot Path Planning (MPP) problem. Mächler [12] found out the differences between PMG and MPP showing PMG models usually assume a central planner aiming to minimize a sequential execution of moves on the graph, there are mainly two distinctions in MPP models; (1) whether the robots execute in parallel or sequential, (2) whether there is a centralized planner or the planning is distributed. Therefore it can be easily concluded that the basic MPP is PMG. Several techniques have emerged in literature to solve sequential MPP. MPP with parallel moves (MPPp) can be defined as a chain of robots that can be moved simultaneously as long as there is an unoccupied vertex at the head on the chain. This particular problem was studied by Ryan in [13] where he separated subgraphs on the base of MPPp. Yu and LaValle [14] added the simultaneous rotation in fully occupied cycle (MPPpr) as natural result for parallel movement. One variant of PMG defined by Yu and Rus [15] allowed simultaneous rotation for sequential problem. They defined a problem of finding a sequence of simple moves and rotations that take initial configuration to the goal configuration thereby transforming into Pebble Motion with Rotation (PMR). PMR model varies from MPPpr in term that the robots are able to move in parallel in case of rotation in fully occupied cycle. The only precondition being that robots can move in sequence. To illustrate the problem, visualize a roadmap $G = (V,E)$, which is a connected graph. Some important variables to be used are; R a set of robots, Γ an initial assignment of robots to vertices $\Gamma: R \rightarrow V$, and a target assignment of robots to vertices $\Phi: R \rightarrow V$. The functions Γ and Φ are total, injective, and non surjective. The path is therefore defined as a map p_i: $Z+ \rightarrow V$. A path p_i is feasible for a robot $r_i \in R$ if it satisfies the following properties: (1) $p_i(0) = \Gamma(r_i)$, (2) for each i, there exists a smallest $k_i^{min} \in Z+$ such that for all $k >= k_i^{min}$, $p_i(k) = \Phi(r_i)$, (3) and for any $0 \leq k < k_i^{min}$, $(p_i(k), p_i(k+1)) \in E$ or $p_i(k) = p_i(k+1)$. If $p_i(k) = p_i(k+1)$, then the robot r_i stays at vertex $p_i(k)$ between the time steps k and $k + 1$. We say that two paths p_i, p_j are in collision if there exists $k \in Z+$ such that $p_i(k)=p_j(k)$ (collision on a vertex, or meet) or $(p_i(k), p_i(k+1)) = (p_j(k+1),p_j(k))$ (collision on an edge, or head-on). The problem is to find set of paths $P = \{p_1, \dots , p_n\}$ such that p_i's are feasible paths for respective robots r_i's and no two paths p_i, p_j are in collision.

The MPP literature uses centralised and decentralised approaches [16]. Each approach can consist of coupled or decoupled robots. Furthermore, due to the basic definition of the problem as NP-hard [17], solution approaches can be categorised based on their completeness for exact and optimisation methods.

In the coupled centralised path-planning approaches, robots act as single robots with multi-bodies and apply a classical single-robot path-planning algorithm. By integrating with complete search methods, such as A*, a coupled algorithm achieves complete and optimal solutions theoretically and probabilistically. In practice, however, the computational time is exponential with the dimension of the configuration space, thus, they are applicable only to small problems. Sharon et al. [18] introduced a new MRPP computing technique by designing the increasing cost tree (ICT) and increasing cost tree search (ICTS). The key idea is to create a snapshot of all robot information (initially the start point of every robot and the cost), represented as states in the ICT attached to the total cost. The tree is spanned for every possible action of every robot. The results show better running time and success rate in large grids.

In the coupled decentralised path-planning approaches, robots apply a distributed MRPP algorithm, decomposing the problem into a set of single-robot problems, which greatly reduces the complexity of each problem and enables the use of single-robot path planners to solve these smaller problems. However, decomposing the problem in a decentralised fashion requires an information sharing and coordination mechanism. The deconfliction technique proposed by Scerri et al. [19] aims to resolve conflicts before they happen. Although this technique produces conflict-free paths, the required synchronisation between robots produces an additional delay. Trodden and Richards [20] propose an improvement in the updating method without synchronisation. In each iteration, one robot re-plans its path and sends it to others, which allows one robot to re-plan in each iteration in order, while all others continue executing their plans to reduce the waiting time. However, a robot with high priority for re-planning has to wait for its turn, which increases the waiting time, and thus, the time cost.

In the decoupled centralised path-planning approaches, paths are planned in two steps: in the first step, each robot's path is calculated individually, and in the second step, the space-time position is calculated to avoid collisions. The first step can be fully distributed while in the second step, there should be communication between robots and priorities may apply in this step. Although these algorithms are distant-optimal, they lose completeness since the paths are calculated completely in the first step, which may contain some conflicts. David [21] proposes a global centralised reservation table where the row for robot i is <location, time>, to avoid conflicts. The table should not contain duplicated values. Although this approach reduces the calculation time, it does not provide a completeness guarantee. A similar reservation table has been used by Stone [6] to solve the car junction problem. Khorshid et al. [22] devised the graph-to-tree decomposition algorithm (GTD). Based on a tree-like graph representation of the problem, they introduced swapping to solve a conflict whenever it occurs.

In conclusion, decoupled approaches run relatively fast, scale well for larger problems but their optimality and even completeness are not always guaranteed [23]. In a coupled approach, the global optimal can be achieved with an overhead of time and computing. Hence, the most relevant problem structure for a heavy traffic control application is one that can be solved by decoupled centralised approaches for three reasons:

- A city is a large environment and coupled centralised approaches scale weakly.
- The overhead of a coupled decentralised approach to achieve the global optimum will affect the time and memory of other robot, which is not important in city configuration.
- A coupled approach supposes that the number of robots is defined before it starts to find the paths and resolve the collisions. However, in a city, any car can start at any time and hence, the car should work individually and resolve collisions as they arise.

III. Methods

When it comes to decoupled centralised approaches, the methods can be classified by their completeness. The exact methods can solve a subclass of MPP completely with a guarantee of the solution. However, despite all of this, their limitation is that they work on only one subclass of the problem. Optimisation methods work on a wider class of the problem than the exact methods and can yield advantage in several aspects such as the path length, execution time or any other metric. Admittedly, optimization methods are not guaranteed to find the solution if there is one.

A. Rapidly-exploring Random Tree (RRT)

A rapidly exploring random tree (RRT) algorithm is designed to efficiently search nonconvex, high-dimensional spaces by randomly building a space-filling tree. The tree is constructed incrementally from samples drawn randomly from the search space and is inherently biased to grow towards large unsearched areas of the problem. RRTs were developed by LaValle, et al [1]. They easily handle problems with obstacles and differential constraints (nonholonomic and kinodynamic). RRT iteratively expanded by randomly selecting a point q_{rand} in the search space, finding the nearest vertex $q_{nearest}$ to that point implies to the tree, and adding new point q_{new} toward the random point with the edge length equals to Δq (Fig.2).

1) iRRT for multi-robots

iRRT is a simple Java program developed by Karaman and Frazzoli [24]. It is dedicated for a single-robot configuration, based on the functionality provided by the iRRT planners. The following extensions are implemented incrementally to fit multi-robot RRT (MRRRT) requirements.

Threads are used to simulate the robots in iRRT to extend the iRRT path planner to support a multi-robot configuration. In addition, robots search based on the A* heuristic where f(n) = min ($d + h$), such that d is the distance from the start point to n and h is the estimated distance from n to the goal point. A collision is detected by evaluating the slope of a selected random point q_{rand}. The technique used in MRRRT with collision avoidance is asynchronous communication between robots through accessing a synchronized shared data centre (server). Each robot maintains the paths of the other robots – they are uploaded onto the server – while planning. Every robot migrates its final path in the server at the end; hence, there is no waiting and no master robot is required. On this basis, collisions can be avoided by checking iteratively all pairs of vertices in every uploaded path. If the randomly selected point q_{rand} is in the x-axis range and y-axis range between two vertices, then all vertices with the same slope as the edge linking those two vertices with q_{rand} are invalid (Fig. 3). In the experiments, both MRRRT – without heuristics – and MARRT* have been evaluated. Fig. 4 shows part of the results.

B. Kornhauser's work

Kornhauser, et al. [11] in their work have provided complete centralized planned procedure to solve all biconnected pebble motion problems with at least one unoccupied vertex. The solutions he has created with upper and lower bounds of $O(n^3)$ moves required on graphs with n vertices and $O(n^3)$ time. However, there is no a single algorithmic description of Kornhauser procedure in the literature. Instead, some works are focused on implementing and improving Kornhauser idea. Moreover, Kornhauser proves a feasibility test of the problem instance in the form of a tree of biconnected (non-separable) components that are linked by chains of vertices with degree two (called isthmuses) as; "*It is impossible for robots to swap if they are separated by an isthmus longer than the number of unoccupied vertices minus two*".

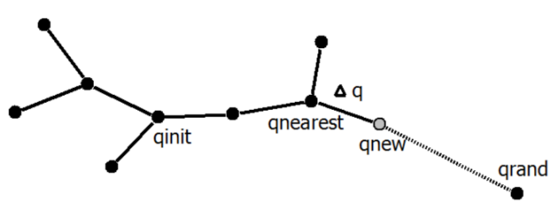


Fig. 2. RRT expansion method

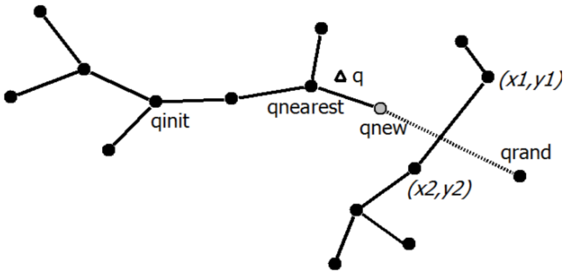


Fig. 3. Validate RRT expansion to avoid collision, if $(y_i-y_1/x_i-x_1) = (y_i-y_2/x_i-x_2)$ AND $xi \in \{x1,x2\}$ AND $xi \in \{y1,y2\}$ then invalid expansion

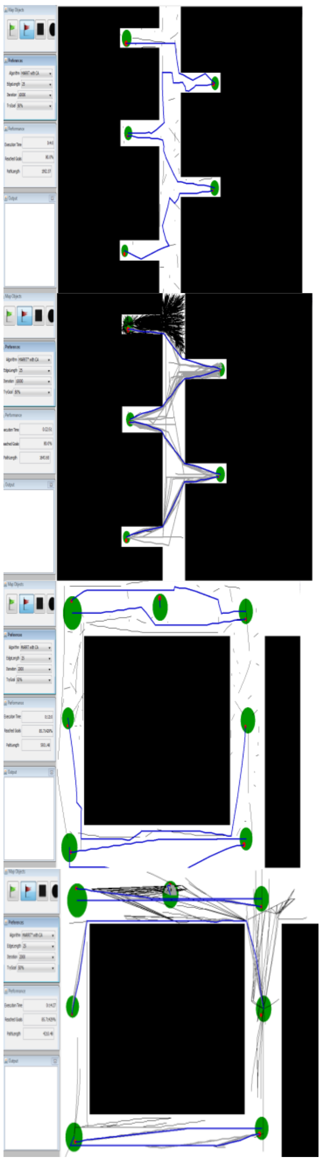


Fig. 4. MARRT paths (left) versus MARRT* paths (right)

To clarify Kornhauser result, consider sequential moves only, Fig.5 shows an instance containing both solvable and unsolvable instances based on Kornhauser condition. Note that it is possible for any of the robots in A1 = {a1…,a6} to swap their positions. The same goes true for the robots in A2 = {a7,a8} as they can exchange their positions too. For example, robot 5 and robot 6 can swap their positions while robot 7 and robot 8 can swap their position. The condition to be met is that no robot from A1 can exchange position with any robot in A2. To understand this, again referring to Fig. 5, if robot 7 wants to swap its position with robot 6, it can be possible only if they move to either the component at the left side of the vertex occupied by robot 6 or to the component at the right side in order to execute swap operation. This swapping would invariably fail due to the reason that during the swapping robots passing the bridge to the left component would stack all robots on it. Hence essentially after this, there will be no possibility to swap unless there are at least enough free vertices to fit all opponent robots on the bridge as well as the two swapping robots. The same thing would happen if the swapping robots pass the bridge to the right component.

C. Push and Swap

Push And Swap (PAS) algorithm provides complete MPP algorithm for problem instances with at least two unoccupied vertices. However, it considers the priority between robots which can cause a limitation and has been solved later in another publication [25]. For each robot *a*, the PAS algorithm finds the shortest path *p** linking the start location of *a* to its goal location, advances the robot through *p** by push and swap algorithms. PAS creates the solution of the problem of n vertices and k robots in $O(n^4)$ time.

1) Push

While the next vertex in the shortest path *p** of robot *a* is unoccupied, push algorithm will advance robot *a*, when another robot *b* is detected on vertex *v* in *a*'s path, the robot *a* has the ability to push it away if it has a lower priority (Fig. 6). If it has a higher priority, the push operator fails, hence, PAS will switch to the swap operator.

2) Swap

When another robot *b* is detected on vertex *v* in *a*'s path and b has higher priority than a. Both robots will advance to the nearest vertex *u* such that the degree of *u* is more than or equal to 3. If the vertex *u* has less than two unoccupied neighbor vertices, then, two occupied vertices should be cleared regardless of the occupying robots' priority (Fig.7). Considering robots *a* and *b* as obstacles, then, robot *a* will swap with robot *b* (Fig. 8). Finally, each robot is affected by the clear operation, which will be resolved by moving it back to its previous location.

D. Push and Rotate

Push and Rotate (PAR) algorithm[2] is a complete version of the PAS algorithm. It creates the solution of the problem of *n* vertices and *k* robots with $O(k.n^3)$ moves and in $O(k.n^5)$ time. It solves any solvable instance recognized by Kornahuser.

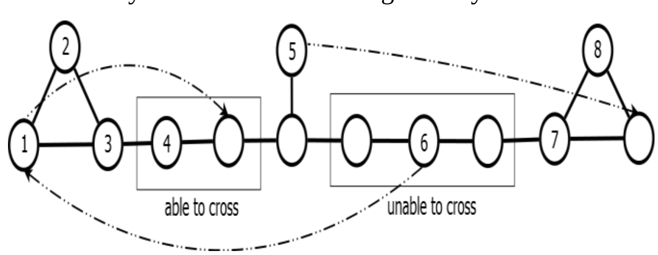


Fig. 5. Graph with solvable and unsolvable instance based on Kornhauser result

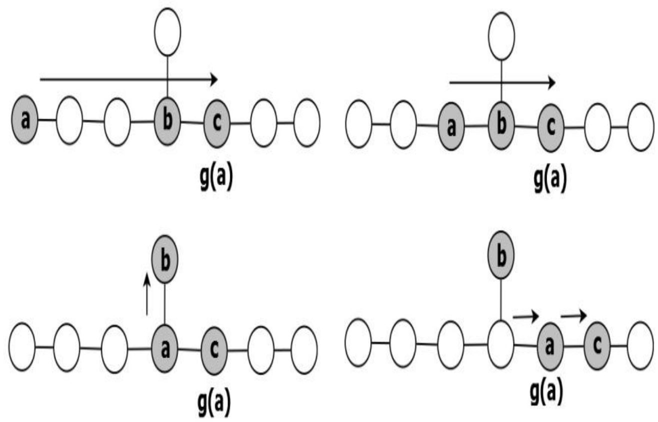


Fig. 6. Push operator: Robot a faces b through its p^* , and b has lower priority than a, robot a pushes b away from its p^*

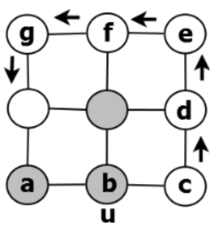


Fig. 7. Robots *a* and *b* are advanced to vertex *u* to achieve swap operation, vertex *u* contains only one unoccupied neighbor, therefore, it should clear the other neighbor. To do it, it should not move *a*, *b* or the unoccupied neighbor, hence, all those vertices will be considered as obstacles for the cleared robots

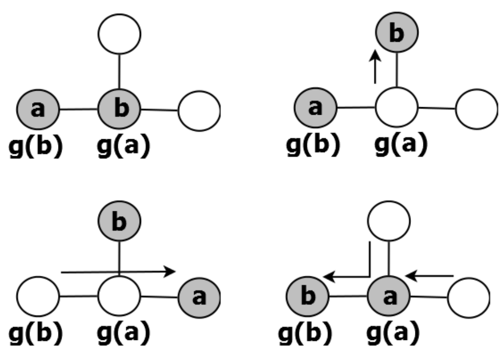


Fig. 8. Swap operator: Robot *a* faces *b* through its SP and *b* has higher priority than *a*, robot *a* and *b* are moved to vertex *u* with degree more than two and swap

result as the instances with number of unoccupied vertices more than to the bridge length minus two. PAR reported four issues contradicting PAS claims. These contradictions will be described in this section exactly as it was presented in [2].

1) Push and rotate proved that multi robot path planning problem can be solvable when Swap fails. The Polygon graph with two unoccupied vertices is a graph conform to Push and Swap requirements. However, MPP problem is solvable in polygon even though Swap fails due to the absence of vertex with degree more than two (Fig.9).

Another example to prove that the problem can be solved when Swap fails is the isthmus graph. When the graph satisfies Push and Swap requirements, under some configuration of robot ordering, the isthmus contains vertex with degree more than or equal three and it is solvable but Swap fails (Fig.10).

2) Push and rotate proved that Clear operation doesn't consider some possibilities when evacuating two vertices in neighborhood of a vertex v.

3) Resolve algorithm in PAS executes recursively to return each robot effected by Swap operator back to its previous location which may lead to swap with other robot. In this case, Resolve algorithm will turn to the swapped robot to resolve it, This will also change the last robots locations, resulting in moving the robots two steps away from their location. This is a possibility which is not considered by Resolve algorithm.

4) Push and Rotate proved that there are new redundant moves resulting after executing Smooth operator in PAS, which may be required to execute Smooth again.

In addition, PAR introduces the rotate operator to resolve cascade moves. The rotate operator is called to move robots forward in a cycle. To do so, one vertex should be cleared by swapping it with a neighboring vertex. Then, all the robots are rotated in the clockwise direction so that any robot affected by the clear operator will be resolved. Fig. 11 describes rotation procedure.

E. Bibox

The Bibox algorithm [4] solves biconnected graphs completely. Initially Bibox decomposes the problem to many handles and one original cycle (Fig. 12). Then, robots with goal locations at the outer handles are solved earlier, and they will be locked and excluded from the search space. This results in a smaller problem, and the original cycle will be solved in different ways. Bibox creates the solution of the problem of n vertices in O(n^3) time and O(n^3) moves. However, Bibox always solves the graph considering the worst scenario. If there are more than two free vertices, it fills those vertices with dummy robots, solves them, and removes their solutions from the final solution. This permits the algorithm of utilise additional free vertices, hence, permits any improvement.

1) Solve handle

Solving a handle means bringing the robots whose goal vertex is the handle, starting from the vertex at the beginning of the handle one by one until all vertices in the handle are finished. If a robot is located outside the handle, bring it to the

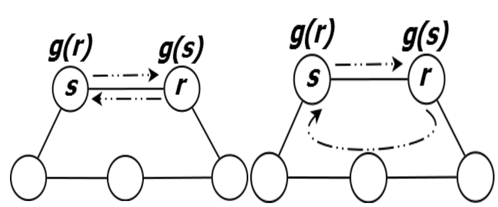


Fig. 9. Polygon graph satisfies Push and Swap requirements (two unoccupied vertices), robot *s* pushes robot *r* to reach its goal position through its p^*,then, *s* is finished robot, *r* tries to push *s* to reach its goal through its p^* and it fails, swap operator will fail also since there is no vertex with degree more than two in Polygon (right), hence, this graph will be unsolvable in Push

and Swap context while it is solvable if there is an alternative path for the robot to follow it (left)

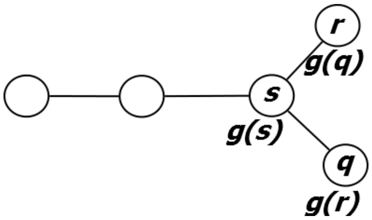


Fig. 10. Graph with isthmus is solvable in Push and Swap context if robot *s* has lower priority among others only

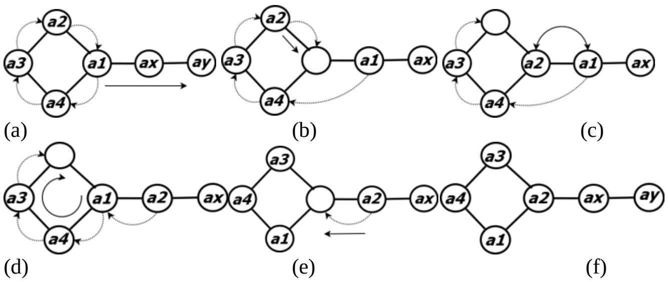


Fig. 11. Rotate operator execution, in the worst case, all vertices in the cycle are occupied

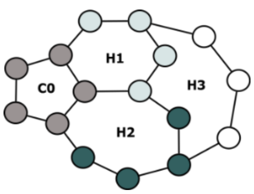


Fig. 12. Decomposing biconnected graph to *i* handles (H_i) and original cycle (C_0)

entering vertex, u, lock the handle to protect the finished vertices from any arbitrary moves, move it to its goal with the rotate operator, and unlock the handle. The idea is that the handle keeps the finished vertices at the beginning, which means they will be rotated and reverse rotated to ensure their robots are back in their locations (Fig. 13). If a robot is located in the handle, rotate the completed vertices until the robot reaches the entering vertex. Advance the robot to any free outer vertex, rotate in the reverse direction by the same path traversed before to protect finished vertices, and continue considering the robot as in the outer robot case (Fig. 14).

2) Solve original cycle

The original cycle will be solved at the end, when the problem consists of a cycle with two unoccupied entering vertices, and all robots in it have their goal inside it also. For each two robots that want to swap, rotate them to the entering vertex, exchange their locations, and reverse rotate to restore the previous locations (Fig. 15).

IV. Analysis

Even though Kornhauser procedure provides complete solution for wide class of problems, it unrecognized wide set of solvable instances by simultaneous rotation. This is because it considers sequential moves only. We can see it vividly, when the instance containing number of unoccupied vertices equal to the maximum bridge length and the problem is defined as MPPp, MPPpr or PMR. In that case the instance is solvable. However, while the bridge length increases, the number of unrecognized solvable instances increases. For instance, the instance described in Fig.16. is a solvable instance in MPPp, MPPpr, PMR boundaries even though the number of unoccupied vertices equal the maximum bridge.

To prove the solvability of such instances, there are two main cases for robot *r* current position and goal position with all other situations being the subcases of these two. The cases are: (1) Current position of robot *r* and its goal position are at a cycle. According to its definition, simultaneous rotation would always be able to pass a robot occupying a vertex in the cycle to its goal on the same cycle even if the cycle is fully occupied, (2) Current position of robot *r* is at a cycle and its goal position is at other cycle. Let *G* be an instance containing two cycles C_1 and C_2, a bridge with length *bl*, and unoccupied vertices *m* equal *bl*. In the worst case, the bridge is fully occupied, the robot *r* at the entrance vertex of C_2 and its goal position inside C_1. Consider two main configuration in this case; (i) All unoccupied vertices are inside C_2 while C_1 is fully occupied (Fig.16). In this configuration, robot *r* would be occupying vertex *v*, which is the entrance to C_2. However, the feasibility would still be guaranteed by moving robot *r* away one step to -*v*, followed by shifting all robots in the bridge to C_2, and passing robot *r* toward C_1 through unoccupied bridge. Once r reaches the head of the bridge, which is the entrance to C_1, the robot will be treated as Case.1. (ii) The unoccupied vertices are divided between C_1 and C_2. In this configuration, robot *r* would be occupying vertex *v*, which is the entrance to C_2. However, the feasibility of the problem would still be guaranteed by moving robot *r* away one step to –*v* followed by shifting half of robots in the bridge to C_2. Once this achieved, robot *r* would be passed towards C_1 through half unoccupied bridge and shifting all opponent robots in the second half toward C_1. Once *r* reaches the head of the bridge, which is the entrance to C_1, the robot will be treated as Case.1. This results can be generalized to grid and bi-connected graphs, when they are contain set of cycles connected by bridge of length one (an edge). Hence, one unoccupied vertex is enough to make the graph solvable.

The MRRRT algorithm appear as favorable optimization algorithms due to the reason that they don't impose any restriction on the roadmap. In addition, the PAS and PAR algorithms appear as preferable algorithms due to its completeness guarantee. Furthermore, the technique of Bibox algorithm is also suited since it is powerful for smaller class of instances, with higher performance. Despite the fact that these algorithm seem most appropriate among the decoupled centralised approaches, these have their own certain theoretical issues;

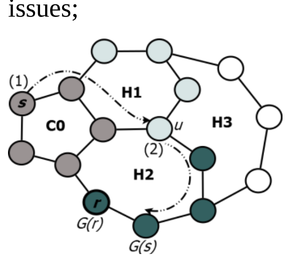


Fig. 13. SolveHandle Case.1, if the robot outside the handle

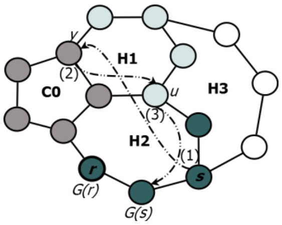


Fig. 14. SolveHandle Case.2, if the robot inside the handle

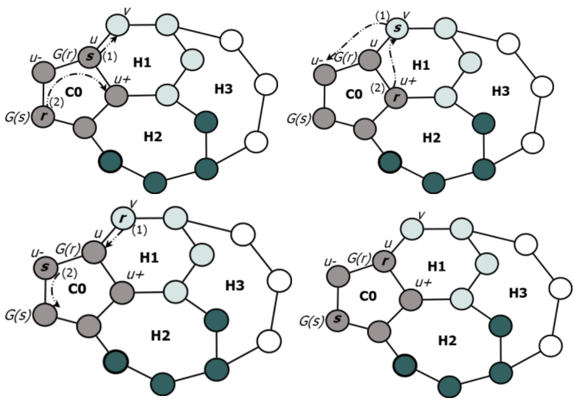


Fig. 15. Solve original cycle

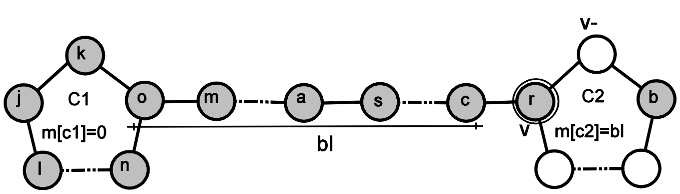


Fig. 16. Solvable instance unrecognized by Kornhauser

1) Kornhauser procedure unrecognized wide set of solvable instances by simultaneous rotation.

2) Since PAR is limited to the solvable instances recognized by Kornhauser procedure, it failed to solve a solvable instance with number of unoccupied vertices equal to the bridge length.

3) Bibox is limited in application since it provides complete solution for only bi-connected graph with two unoccupied vertices.

4) Bibox always solves the graph considering the worst scenario. If there are more than two unoccupied vertices, it fills those vertices with dummy robots, solves them, and removes their solutions from the final solution. This permits the algorithm to utilize additional unoccupied vertices, hence, permits any optimization.

5) There are wider class of solvable instances with only one unoccupied vertices, which is excluded from PAS, PAR and Bibox assumption.

V. Experimental Results and Discussions

The end objective was to answer the question: what is the benefit of these algorithms? To answer this question, three main factors of the problem are evaluated; (1) the algorithms' execution time to find the whole path, (2) the rate of success results in a fixed time period, (3) and the total path length calculated mathematically as the sum the number of vertices composing the path. All experiments are employed in Ubuntu Dell M5110 laptop, Intel(R) Core(TM) i7 CPU@ 2.20GHz. A series of experiments were conducted to compare between MRRRT, MRRRT*, PAS, PAR and Bibox algorithms. The factors are examined ten times on biconnected graph, tree-with-cycle-leaves (TWCL) and six benchmark problems proposed in [3] that describe different scenarios of intersecting paths (Fig.17).

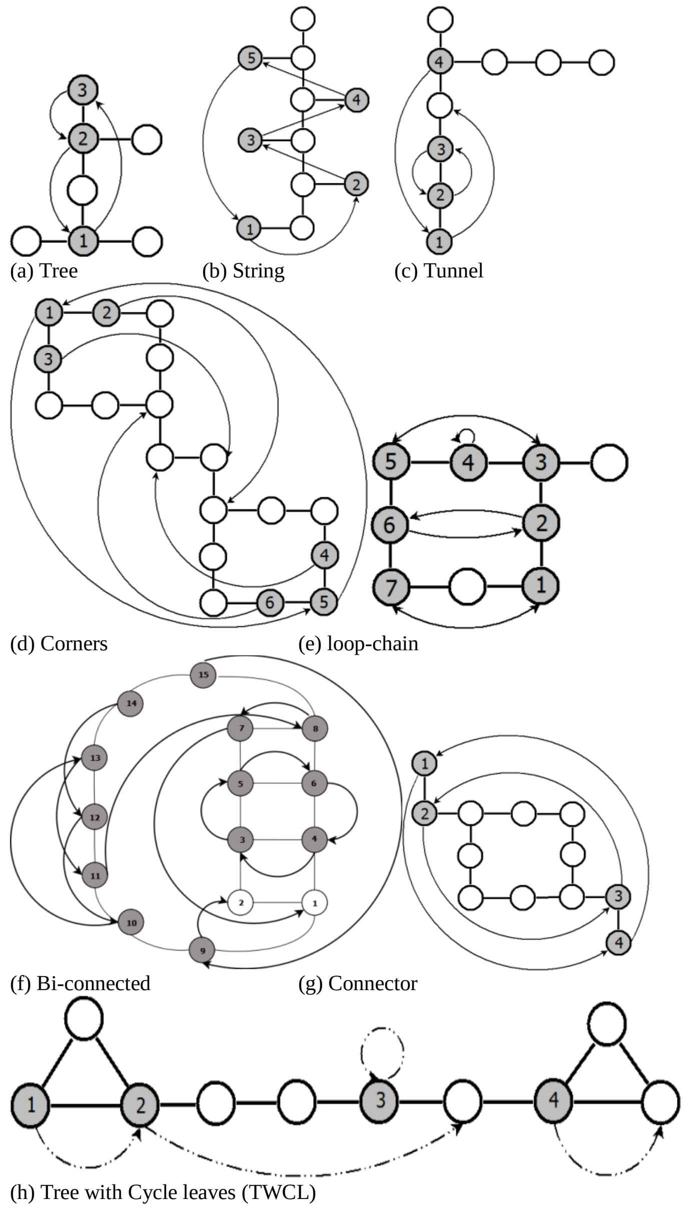


Fig. 17. Benchmark problems

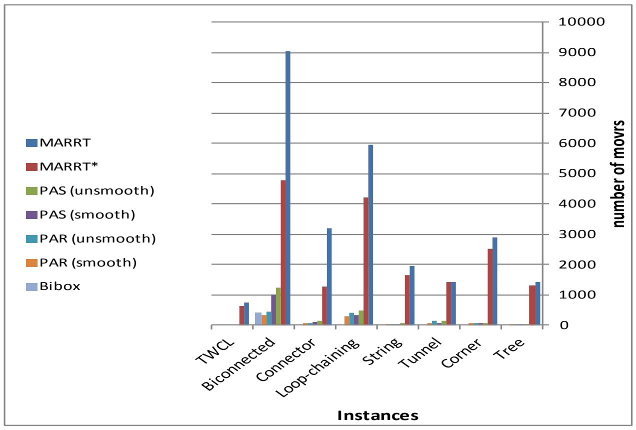


Fig. 18. Path length defined by number of moves

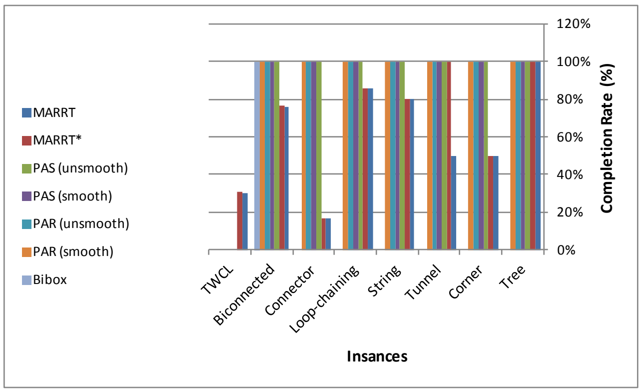


Fig. 19. Completion rate defined as the ratio of reached robots to all robots

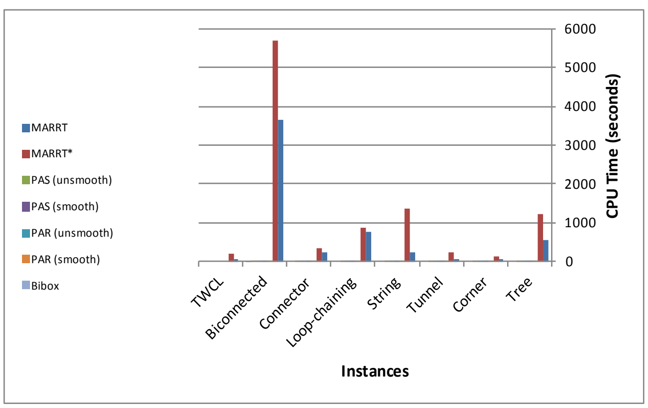


Fig. 20. CPU time for all algorithms

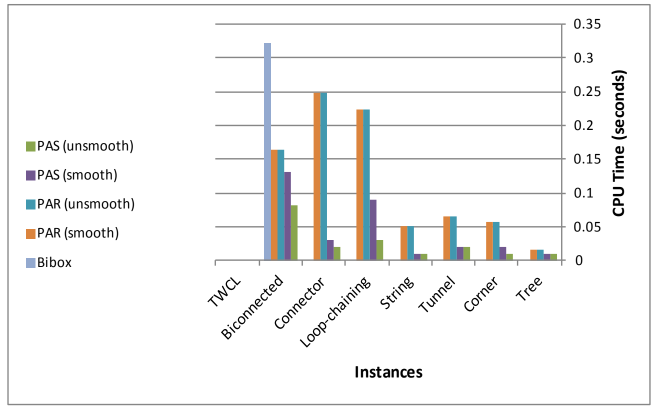


Fig. 21. CPU time for all algorithms except MRRRT and MRRRT* algorithms (To see the differences between others)

The results in Figs. 18–21 show that, for all problems, MRRRT* outperforms MRRRT in finding shorter paths for the robots since it uses the A* heuristic. However, MRRRT* consumes more computation time than MRRRT mainly for tree and biconnected problems, since it explores all valid paths then selects the shortest one. On the other hand, all PAS and PAR versions outperform MRRRT versions in minimising the path length due to the basic difference between the planners, which is that MRRRT works in an unknown environment while PAS works in a fully known environment, which reduces the overhead of path exploration. For the same reason, the execution time for PAR is much less than for MRRRT. Furthermore, all PAS and PAR versions outperform MRRRT versions in the total number of achieved goals due to the completeness guarantee provided by PAS and PAR and since MRRRT reserves the full path of a robot, which reduces the space for other robots. However, the higher-priority robots may permit a lower-priority robot to achieve the shortest path. In addition, Bibox has better calculated path lengths than other algorithms in the class it solves. Finally, PAS and PAR fail to solve the TWCL class, which is a subclass of the solvable problems since it contains bridge length equals to the number of unoccupied vertices minus one while MRRRT and MRRRT* algorithms solve that instances since they don’t impose any restriction on the graph topology.

VI. Conclusion

In this survey, the MPP literature for heavy traffic control was briefly reviewed. The closely related structure was discussed and a practical comparison was done between an optimisation technique, RRT, and three of the exact techniques, PAS, PAR and Bibox. Their specifications, strengths and weaknesses were compared, as summarised in Table 1. The experiments showed that MRRRT is the best for exploring any search space and optimizing the solution. On the other hand, PAS, PAR and Bibox are better in terms of providing a complete solution for the problem and resolving collisions in significantly much less time, the analysis, however, shows that a wider class of solvable instances are excluded from PAS and PAR domain. In addition, Bibox solves a smaller class than the class solved by PAS and PAR in less time, in the worst case, and with a shorter path than PAS and PAR. Based on the results, future work may look at these weaknesses in Table.1 as holes for contributions.

TABLE I. SUMMARY

Method Criterion	MRRRT* [1]	PAS [3]	PAR [2]	Bibox [4]
Environment information	Unknown/ dynamic	Unknown/ dynamic	Known/ dynamic	Known/static
Assumption	Any problem instance	Graph with at least two unoccupied vertices.	Graph with at least two unoccupied vertices.	Biconnected graph with two unoccupied vertices.
Completeness	Incomplete	Complete (except the instances reported in [2]).	Complete	Complete
Path Complexity	-	-	$O(n^3 . k)$[2]	$O(n^3)$
Time Complexity	Since it works in unknown environments and selects the shortest path among different paths, the time is the longest among other planners	-	$O(n^5 . k)$[2]	$O(n^3)$
Strengthens	- Capability to explore unknown environment. - The use of online path planner (CL-RRT) makes the proposed planner applicable to the dynamic environment. - Finds the shortest path among different paths by A* heuristic.	- Simple. - The experiments show high efficient results in term of the computation time, solution length and the success rate with high scalability on most of the cases. - Merges the advantages of decoupling approaches in terms of fast calculations, and the advantages of coupling approaches in term of local robots negotiation	- Simple -The experiments show high efficient results in term of The computation time, solution length and the success rate with high scalability in all cases. -Merges the advantages of decoupling approaches in terms of fast calculations, and the advantages of coupling approaches in term of local robots negotiation	- Achieves the least time and path length proved by Kornhauser.
Weaknesses	- The priority of the higher robots may permit a lower robot to finds its paths - Cooperation process may add additional computing overhead. -Optimizing the path may add additional computing overhead	- The priority of the higher robots may permit a lower robot to achieve shortest paths. -There are wider class of solvable instances which is excluded from PAS assumption.	- The priority of the higher robots may permit a lower robot to achieve shortest paths. -There are wider class of solvable instances which is excluded from PAR assumption.	Solves the instance in its worst case, which permit any improvement.

REFERENCES

[1] S. M. LaValle, "Rapidly-Exploring Random Trees A New Tool for Path Planning," 1998.
[2] B. d. Wilde, A. W. ter Mors, and C. Witteveen, "Push and Rotate: a Complete Multi-agent Pathfinding Algorithm," Journal of Artificial Intelligence Research, pp. 443-492, 2014.
[3] R. Luna and K. E. Bekris, "Push and swap: Fast cooperative path-finding with completeness guarantees," in IJCAI, 2011, pp. 294-300.
[4] P. Surynek, "A novel approach to path planning for multiple robots in bi-connected graphs," in Robotics and Automation, 2009. ICRA'09. IEEE International Conference on, 2009, pp. 3613-3619.
[5] E. Guizzo, "Three Engineers, Hundreds of Robots, One Warehouse," IEEE Spectr., vol. 45, pp. 26-34, 2008.
[6] K. Dresner and P. Stone, "A multiagent approach to autonomous intersection management," Journal of Artificial Intelligence Research, pp. 591-656, 2008.
[7] J. Leitner, "Multi-robot cooperation in space: A survey," in Advanced Technologies for Enhanced Quality of Life, 2009. AT-EQUAL'09., 2009, pp. 144-151.
[8] J. M. Roberts, E. S. Duff, and P. I. Corke, "Reactive navigation and opportunistic localization for autonomous underground mining vehicles," Information Sciences, vol. 145, pp. 127-146, 2002.
[9] D. Nieuwenhuisen, A. Kamphuis, and M. H. Overmars, "High quality navigation in computer games," Science of Computer Programming, vol. 67, pp. 91-104, 2007.
[10] R. M. Wilson, "Graph puzzles, homotopy, and the alternating group," Journal of Combinatorial Theory, Series B, vol. 16, pp. 86-96, 1974.
[11] D. Kornhauser, G. Miller, and P. Spirakis, Coordinating pebble motion on graphs, the diameter of permutation groups, and applications: IEEE, 1984.
[12] P. Mächler, "Pebbles in Motion Polynomial Algorithms for Multi-Agent Path Planning Problems," Master of Science in Computer Science, Department of Mathematics and Computer Science, University of Basel, Basel, 2012.
[13] M. R. K. Ryan, "Exploiting subgraph structure in multi-robot path planning," Journal of Artificial Intelligence Research, pp. 497-542, 2008.
[14] J. Yu and S. M. LaValle, "Multi-agent path planning and network flow," in Algorithmic Foundations of Robotics X, ed: Springer, 2013, pp. 157-173.
[15] J. Yu and D. Rus, "Pebble motion on graphs with rotations: efficient feasibility tests and planning algorithms," in Algorithmic Foundations of Robotics XI, ed: Springer, 2015, pp. 729-746.
[16] J.-C. Latombe, "Robot Motion Planning, Chapter," 1996 1991.
[17] C. H. Papadimitriou, P. Raghavan, M. Sudan, and H. Tamaki, "Motion planning on a graph," in Foundations of Computer Science, 1994 Proceedings., 35th Annual Symposium on, 1994, pp. 511-520.
[18] G. Sharon, R. Stern, M. Goldenberg, and A. Felner, "The increasing cost tree search for optimal multi-agent pathfinding," Artificial Intelligence, vol. 195, pp. 470-495, 2013.
[19] P. Scerri, S. Owens, B. Yu, and K. Sycara, "A decentralized approach to space deconfliction," in Information Fusion, 2007 10th International Conference on, 2007, pp. 1-8.
[20] P. Trodden and A. Richards, "Robust distributed model predictive control using tubes," in American Control Conference, 2006, 2006, p. 6 pp.
[21] D. Silver, "Cooperative Pathfinding," in AIIDE, 2005, pp. 117-122.

[22] M. M. Khorshid, R. C. Holte, and N. R. Sturtevant, "A polynomial-time algorithm for non-optimal multi-agent pathfinding," in Fourth Annual Symposium on Combinatorial Search, 2011.
[23] Q. Zhu, J. Hu, W. Cai, and L. Henschen, "A new robot navigation algorithm for dynamic unknown environments based on dynamic path re-computation and an improved scout ant algorithm," Applied Soft Computing, vol. 11, pp. 4667-4676, 2011.
[24] S. Karaman and E. Frazzoli, "Sampling-based algorithms for optimal motion planning," The International Journal of Robotics Research, vol. 30, pp. 846-894, 2011.
[25] Q. Sajid, R. Luna, and K. E. Bekris, "Multi-Agent Pathfinding with Simultaneous Execution of Single-Agent Primitives," in SOCS, 2012.

Improving Service-Oriented Architecture Processes in Process of Automatic Services Composition Using Memory and QF, QWV Factor

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***Abstract*—The application of service-orientated architecture in organizations for implementation of complicated workflows in electronic way using composite web services has become widespread. Thus, challenging research issues have also been raised in this regard. One of these issues is constructing composite web services by workflows. These workflows are composed of existing web services. Selections of a web service for each of workflow activities and fulfilling users' conditions is still regarded as a major challenge. In fact, selection of a web service out of many such web services with identical function is a critical task which generally depends on composite evaluation tool of QoS. Previously proposed approaches do not consider exchange restrictions on the composition process and internal processes of architecture and previous experiences, and they ignore the fact that value of many of QoSs depends on the time of implementation. Selection of web services only based on QoS does not bring about optimal composite web service. Thus, till now, no solution has been proposed that performs composition process automatically or semi-automatically in optimal manner**

Objective: identification of existing concerns on composition of services and then designing a framework to provide a solution which consider all concerns and finally performing tests in order to examine and evaluate proposed framework

Method: in the proposed framework, elements affecting management of service-oriented architecture processes are organized according to a logical procedure. This framework identifies processes of this style of architecture based on requirements in service-oriented architecture processes management and according to qualitative features in this area. In the proposed framework, in addition to using existing data in the problem area, existing structure and patterns in the area of software architecture are also utilize, and management processes in service-orientated architecture are improved based on propriety of available requirements. QWV are qualitative weighted dynamic features which indicate priority of users, and QF is quality factor of service at the time of implementation which is weighted in the framework. These factors are used for constructing composite web service. Multifactor computing is known as a natural computational system for automating the interaction between services. The factors in multi-agent systems can be used as the main reliable mechanism for the control which usually use data exchange for accelerating their evaluations. For identification of all concerns in the solution space, many aspects should be examined. To this end, classes of agents are defined which investigate these aspects in the form of four components using repository data.

Results: proposed framework was simulated by Arena software and results showed this framework can be useful in automatic generation of needed services and meet all concerns at the same time. Results support that using agents in the model increased speed of accountability and satisfaction of users as well as system efficiency.

Keywords*—Service-orien ted architecture; process management; multi-agent systems

I. Introduction

Service-orientated architecture provides a collection of designing principles for operationalization and implementation of automatic commercial process in heterogeneous environments[1]. Service-oriented architecture includes management of applications, services, processes, firmware, infrastructures and software tools in line with business objectives. Service-oriented architecture process management is classified into service-oriented architecture lifecycle management, service management, service change management, service composition management and service interaction management, service registries and exploration management. Service-oriented architecture management is actually a multi-faceted task which covers IT management and Business Service Management. There are several ways for implementing SOA, but the most famous and most popular way are run by Web Service technology[2] that depends on infrastructure of World Wide Web and use of open XML standards such as SOAP, WSDL. Another benefit of using web services is their interoperability between different heterogeneous organizations or units [3].

Over recent years, the number of web services with identical performance and different quality has increased and is still growing [4] which leads to increased complexity of composition[5]. Cost and efforts for constructing composite services in manual way is certainly higher than composition cost as automatically[6]. The other reason which increases cost of manual effort compared to automatic efforts is that usually demands are issued continuously or previous demands are changed. Thus, there is need for techniques which automatically compose services and reduce cost and effort to respond to needs of user[7]. Composition of services based on QoS is one of the issues raised in service-oriented architecture.

Most of the available methods consider QoS as static. It means that fixed values are considered for QoS values in all user demands over the time. While value of these features depends on the time and have different values depending idea of the user on different applications.

Generally, the lifecycle of a composite web service includes three stages: 1. Design, 2. Implementation and supervision, 3. Re-engineering [8, 9]. In the first stage, obvious features of composite web service are identified. In the second stage, at the time of design and supervision, addressing and implementation of composite web services and finding solutions and errors which emerge in this stage is done. Finally, in re-engineering stage, features of composite services are modified which depends on the data obtained from second stage. The solutions for performing this process are also provided as dynamic (like[10]) which are capable of review in composite web service immediately after second stage (dynamic binding). In this paper, a model is proposed which considers three stages of lifecycle of composite service construction. First stage is described in more details in this paper, and subsequent stages are extended in the future works.

In the proposed model, three stages are organized by agents in four components and depository. Ten classes of agents are embedded in components and perform their tasks using depositories. In the stage of design, user interface agent provides the demand for application agent following taking user demands and transforming them to standard format. The application agent turns user's need to tasks and workflow of composite web service is generated. Second stage, that is, discovery of suitable candidate services for each activity, is done by registry factor. For accelerating this operation in the proposed model, services are grouped in sub-domains considering their functions by grouping agent in design stage. Registry agent searches for relative service for each task in sub-domains. If corresponding service is not found, it searches for previous composite services in the system memory, i.e. solution depository. In case of not finding suitable service, demand is referred to the composer agent service composer should generate workflow manually or semi-automatically. This workflow is logically as an ordered set of activities that each activity is performed by an atomic service. Following selection of suitable candidate services for taking part in composition operation, third stage is performed. That is, selection of the best service out of candidate services for taking part in composition. Registry agent does selection under supervision of manager agent using genetic algorithm considering dynamic values of QoS and QF. QoSs are regularly updated by evaluator agent. QWV is qualitative features vector considered by the user, which indicates significance of each feature in the view of user. Quality of service in web services (QoS) includes some non-operating characteristics such as cost performance, runtime, the availability, performance and security success rate[11]. QWV is weighted value of QoS which is dynamic and is weighted over the time according to priorities of user by operating user interface and provides optimization. Value related to service quality factor (QF) denotes quality of service implementation and availability of service. It is stored in model memory and updated by registry agent in Meta data of system. Following selection of suitable service out of candidate services, last stage of design is finished. Second phase of lifecycle, i.e. implementation and supervision, is followed by service agent, management agent, and security agent, and processes related to third cycler of composite web service lifecycle is performed in SME component. In our model, agents are put in components and they perform respective operations using depositories which are the same as model memory. The purpose is generating composite service which has non-functional features optimal for user. As explained in previous paragraph, designing composite service is a time-consuming and complex process, and if it can be accomplished automatically, certainly less costs and efforts are needed compared to manual manner[6].

Service-oriented architecture lifecycle management, service management, service changes management, service composition management, service interaction management, and service registries and exploration management is done by agents in the model. Multi-agent system performs a combination of managerial affairs in service-oriented architecture. Data needed by the system are extracted by agents and embedded in the Meta data depository. These data are updated and managed in registry service table, and they would be used at the time of implementation.

Overall goal of previous works is finding administrative workflow which can generate services in a composite web service to reach requested functionality. The other point is the way of selecting services out of candidate services which has been done for predefined workflow to reach non-functionality tasks as QoS. In the previous works, agents have not be used comprehensive in the whole architecture processes [12, 13]. They used multi-agent system as intelligent control layer for managing affairs. Establishment of interaction among services [14] and manipulating handling changes [15] are among tasks which led to emergence of agents in architecture composition.

In summary, the proposed framework deals with classification of service-oriented architecture processes. In service composition part, using quality factor definition it was practically shown that agents can make service-oriented architecture activities considerably more effective and efficient by applying management and control over model components and storage and updating model knowledge in depositories. Eeach part in the future model will be provided for optimization of these processes in model components and depositories. Works done for this paper are explained in detail in the following:

1) Firstly efforts for automatic composition of services were reviewed and analysed and existing concerns and gaps were identified.

2) Existing processes in service-oriented architecture were identified and they were structured in the proposed model.

3) Agents were used for improving processes in the architecture.

4) Internal memory was added to the system by adding depositories to the framework.

Priorities of this framework over previous methods include as follows:

1) Quality factor (QF) indicates framework's evaluation of provided services which is more reliable criterion for selection of optimal services beside QoS which is provided by service generator dynamically known as QWV.

2) Weighing quality factor (QF) by agents in the framework allows evaluation of services in implementation stage.

3) QWV is weighed by user interface factor and includes user priorities using updated values of QoS, and this value is used by composer agent for constructing composite service.

4) Composer agent identifies the best existing compositions using compliance function, in which use QoS, user priorities, and framework evaluation of the service is also considered. It is performed by genetic algorithm. The best composition is referred to the registry agent. Using QF and QWV factors makes genetic algorithm more effective compared to similar works in selection of the best composite services.

5) For filling the existing gaps in composition issue, this paper provides a framework which considers all issues in architecture. Using agents beside depositories reduces necessity for relationship between framework and user and it allows automatic generation of composite web service to meet user needs and covers all existing concerns in composition issues.

It is known that composition is a multipurpose problem. Thus, in the proposed model, it is attempted to consider several problems simultaneously in the composition. A new approach is provided for multipurpose problem and currently a comprehensive introduction and experimental approach for it is discussed. In automatic multipurpose composition there are some concerns. Proposed framework considers composition with all aspects. For composition, a fitness function is used and QF and QWV are embedded in it. Agents are used for implementing GA in order to update variables. Features of the proposed model is different from most of traditional methods and can be used for other multipurpose problems with similar features. As in the proposed framework, specific philosophy and view is used in classification of architecture management processes, needed issues are described in explanation of the model.

In the following, the paper is organized as follows: in the second section, previous works are reviewed and the concepts used in proposed framework are described in the third section. Standard of service definitions in the framework and ranking services are also described. In the fourth section, for evaluation of the framework, curriculum of second semester 2015 – 2016 in Islamic Azad University of Karaj is implemented in the framework and the last section is devoted to conclusions and future work.

II. Review Of Literature

In this section, previous studies and works are reviewed. Many works have been conducted on service changes management area which [16] can be an example. In[3] using intelligent solution for finding optimal solution is suggested. In Table 1 part of works on service composition area is shown. Service composition issue is divided into two main fields including service selection and service composition[17]. In Figure 1, service selection methods are classified according to[18]. In composition of services, each selected service has specific administrative capability and it is unique. These services should be implemented in the form of a composite service and provide needed capabilities. Workflow implicitly makes this composite service. For composition of works, both semantic links and key terms comparison can be used. Semantic links will be used in the future works.

TABLE I. A Comparison Table for Current Works

Author	approach	QoS_Aware	Semantic Based	Co-agent	Using optimization algorithms
Mohammed, et al. [19]	Heuristic algorithm	Yes	No	No	Yes
. Wang, et al. [20]	ant colony optimization algorithm	Yes	No	No	Yes
X. Wang, et al. [21]	bee colony approach	Yes	No	No	Yes
T. Zhang [22]	particle swarm optimization algorithm	Yes	No	No	Yes
V. S. Jeure et al. [23]	particle swarm optimization algorithm	Yes	No	No	Yes
X. Zhao, et al. [24]	Immune algorithm	Yes	No	No	Yes
M. Fahad, et al.[25]	Semantic-based BusinessProcess Execution Engine	Yes	Yes	No	No

III. Concept of Proposed Framework

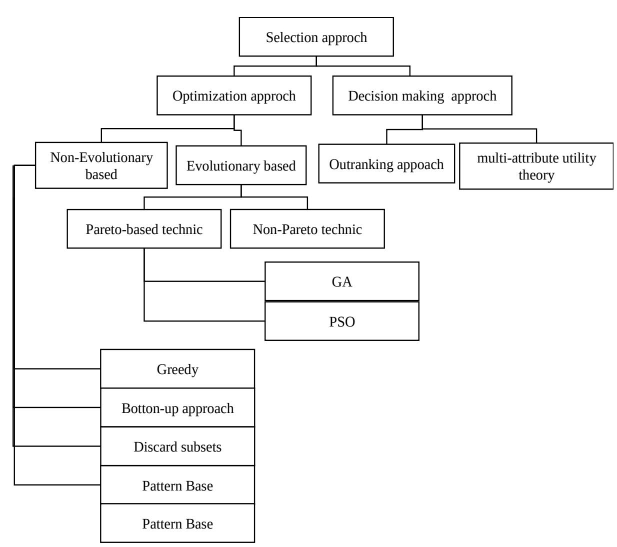

Fig. 1. Web service selection approaches [18]

In this section, assumptions, symbols and icons used in the model are described. The proposed model is composed of components and depositories. Each component is a computing entity which is an interconnected collection of the system functionality requirements. Components communicate through one or more ports to the environment. Ten categories of agents help components so that system requirements are removed. The overall structure of the proposed framework has been shown in Figure 2. Business Process Management (BPM) is take from stakeholders by user interface agent and it is stored in this component under Request For Change (RFC) standard form. Requirements in this framework are stated under title of RFC so that it can be integrated to ITIL framework in the future. Problem definition in the proposed framework is defined by RFC which is an ordered triple: RFC (T, QWV, C)

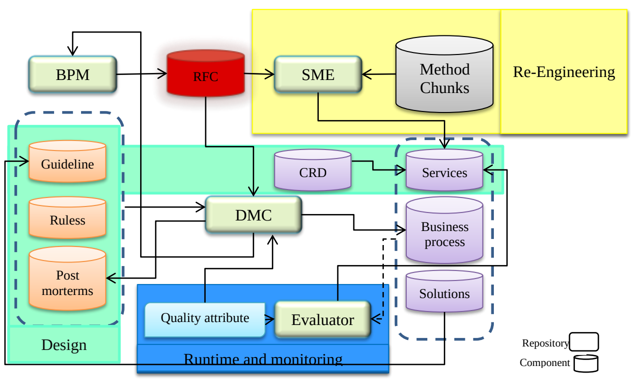

Fig. 2. The structure of the proposed framework

- T specifies a set of works composed of $\sum_{i=1}^{n}$ task ti where n denotes total number of works. Application agent is responsible for developing workflow in BPM component. Service workflows are implemented by modeling languages (BPEL)[19]. Application agent produces and manages problem statement, that is, RFC (Figure 3).

- QWV is weighted vector of QoS which specifies user priorities on qualitative features of service (QoS) that is composed of: QWV = $<qw_1, qw_2, qw_3, \ldots, qw_m>$

m denotes number of qualitative features which are important for system in the framework and are obtained by manager agent at the beginning of the work based on the results taken by application agent. User priorities are reflected in this weighted vector.

- Constraints (C) determine constraints specified by the user.

- In terms of emission of changes in service depository in the framework, our design is taken from active depository style. Some services have been specified in depository which are informed of specific events shared in the depository. These services inform changes in service depository to DMC component.

Situational Method Engineering (SME) component reengineers in lifecycle of composite web service using method chunks. Decision-Making Center (DMC) component has axial stats in proposed framework. In this component, different concepts are put together and general goals of framework are realized. In fact, it can be stated DMC component has decision making status in the framework.

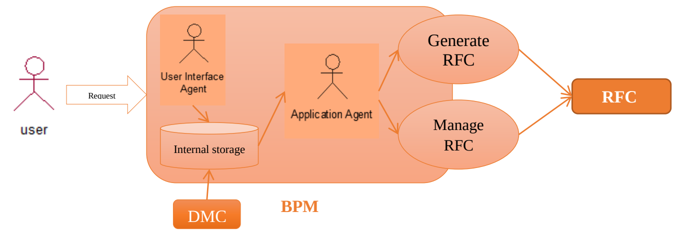

Fig. 3. BPM components structure

Manager agent contains a series of principles, rules, guidelines, tools and previous experiences (located in depositories) which decision making is done using them. Overall this component is shown in Fig 4. Manager agent in this component makes decision considering priorities of QWV and QoS stakeholders for retrieval of agents[26]. Solution repository component plays key role in realization of approach based on the pattern adopted in framework. Significant point in proposed framework is that it has learning capability and solution repository is raised as one of the memories of this intelligent framework. In other words, this component of architecture can be extended by new solutions. In addition, possibility for correction or changing existing solutions is also available. In relation with the way of storing these solutions, registry agent with the help of grouping agent, models solutions in the form of modeling language BPMN. BPMN can be transformed into BPEL standard. Thus, maximum compatibility and standardization in the framework is prepared and it allows that business processes are easily developed with extending solutions.

In the proposed framework, each service is connected to a standardizer known as common rules database (CRD). This unit is a basis of existing rules and norms, related to application case, which is embedded in the proposed framework in order to chat and negotiate with CRD connected to different services. Proposed framework is shaped based on reference layering of service-oriented architecture[27, 28]. Multi-agent system is used for improving service-oriented architecture processes (Figure 5). In evaluator component, registry agent scores services, business processes and solutions considering their qualitative features, and turns QoS value from static to dynamic state. Here two working areas are distinguished. First area supervises measurement of qualitative features. Second area scores these cases given their qualitative features. In fact, in the first area, measurement and identification of qualitative features is dealt and on the other hand, multivariate decision making is faced in the second area. In relation with measurement of qualitative features, expertness is the most important point (Figure 6). In other words, considering complexity and qualitative of these criteria, human agent or expertness role is bolded. The methods which have addressed this issue have used scenario-based techniques and in addition they have also utilized controlling and screening tools. In the future works, a fuzzy system will be used in this section for measuring qualitative features.

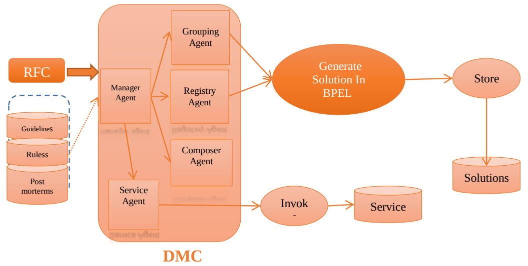

Fig. 4. DMC components structure

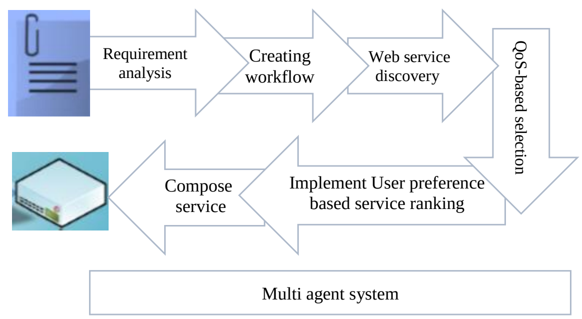

Fig. 5. DMC components structure

In relation with scoring services, business processes and solutions, there are different approaches, which somehow are based on scoring by experts In the proposed framework, scoring is delegated to registry agent, which performs scoring by combination of results obtained from solutions depository and QF and results taken from BPM component. The value related to QF, QWV is also updated in this component.

A. *Defining Service in Framework*

In order to assure comprehensibility of service by the machine and automatic relationship without human intervention, each service is defined in the framework by tuples.

Tuple :(ID,I,O,P,E,NF)

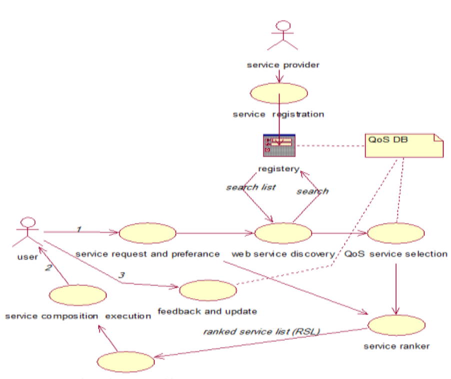

Fig. 6. Scoring the values of QoS, by experts

Values of this senary tuple are described in the following:

ID: its value is unique and specifies identity and name of service.

I: it specifies service input. It determines requirements needed by the service at the retrieval time for successful invoking the service.

O: It specifies service output when the service is invoked successfully.

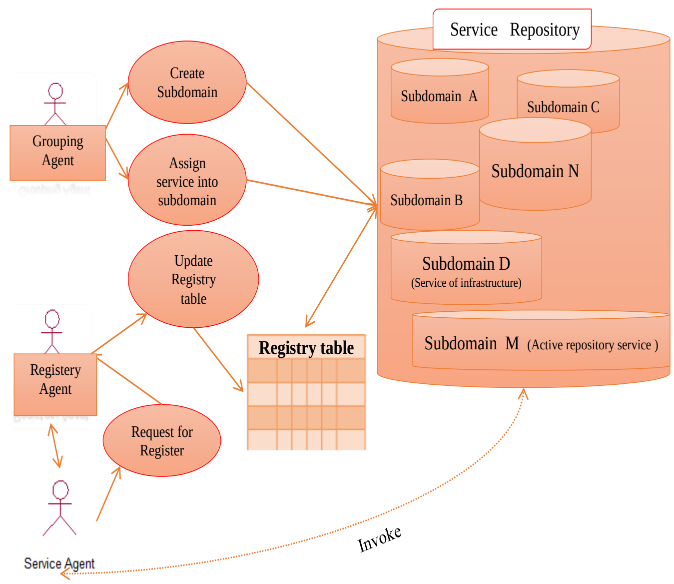

Fig. 7. Repository Service in the proposed framework

P: pre- requirements; a collection of conditions which should be prepared prior to service retrieval so that service is invoked successfully.

E: Result; a set of conditions that must exist following successful invoking the service.

Data conversion services which are responsible for the task of converting between different technologies are among these services which has been shown in Fig 7.

NF: Specifies non-functional features of service which include QoS and QF, and compliance function will be defined for it considering each problem.

B. *Ranking Services*

The core of automatic composition of services is based on algorithm for ranking QoS of services according to user demand and service composition algorithm (Algorithm 1). Values related to QoS of each service is weighted at the time of service recording by service generator in registry table. Agents in the framework are responsible for supervision over these features and if necessary, these values are updated by service agent. QWV value is recorded in features depository following imposing weights by application interface.

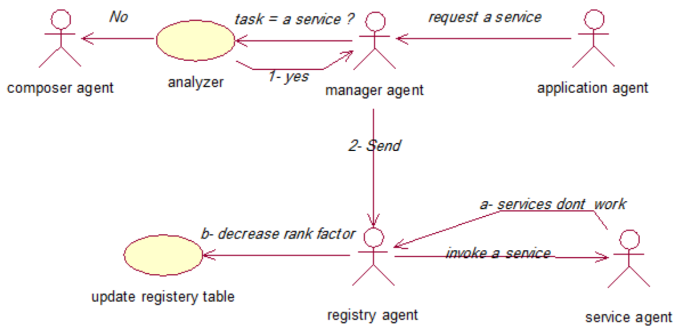

Fig. 8. Request a service use case diagram

Algorithm 1 : User Preference Based web service ranking algorithm (RFC (T,QWV,C), WS)

// RFC: User Request
// S_i: web service
// SDSi: sub domain of Si
// t_i: Task involved in user request
// WSL_i: list of web services in the registry table
// SL_i: search list
// FL_i: filtered list
// QFRL: QF ranked List
// QWV: QoS weighted vector
// $\langle QWV\rangle = \langle qw_1, qw_2\rangle$
// qw 1: Cost Weight
// qw 2: Response Time Weight
// CSLi: composed Services List (Register in solution repository)
Begin
(1)For each task t_i in RFC
    (2)Discover (WSL_i, SDS_i)
        (3)For each S_i in SL_i
        Do
        (4)If (Availability == true) & (QF>0)
            (5)SL.add()
        (6)Endif
        (7)EndFor
    (8)QoS based Service Selection (SL)
    (9)Compute QoS Rank(FL)
    (10)Final Rank based Sorting (QFRL,QWV)
    (11) Apply Genetic Algorithms
(12)End For
(12)Return CSL
End

QF value is weighted by the framework. Initial weighing for this factor is set as 1 in all services. When the service cannot work, fails, or it cannot be found, value of this factor is reduced according to Formula (1), or when performance of it is reduced compared to previous runs, this value is decreased. As shown in Fig 8, registry agent is responsible for updating this value in each service. QF is increased when the assigned works are properly done, and it becomes a basis for service selection. α is wegithed by the framework considering the problem($0 < QF \leq 1$) , ($-10 \leq \alpha < 10$) . If non implementation of the service has considerable impact on the system, this value is considered as large, otherwise, smaller values are considered for it.

$$QF(t+1) = QF(t) - 0.01 * \alpha \qquad (1)$$

I, P value is weighted in BPM component by user interface agent given features of the service demanded by the user, and it is stored in RFC depository. DMC component is responsible

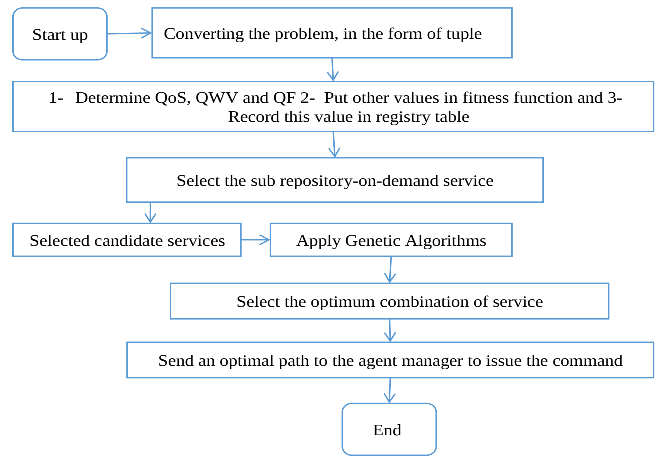

Fig. 9. Flowchart of combined service in the proposed framework

for making decision on continuing the work. Process of the works is shown in summary in

ure 9.

A composite web service (CWS) is a set of services, where features of each service are specified by senary tuple. Generator of composite service should assign a tuple to this set which contains features of composite service.

In tuples I, O, P, E service performance is shown. Using tree structure described in[29], CWS performance in its corresponding tuple is shown. Non-functional features of this composite service are weighted in NFi which includes two parts; QF which takes a default value and QoS, composite web service, which is calculated by composer agent. Composition of web services is done through four ways[30] which is given in Figure 10. In composite structure (sequential (a), cycle (b), parallel (c), and branch structure (d)) works are run sequentially and, each work is run several times in loop structure. In parallel structure, all work can be done at a time and after completing all tasks, parallel structure of the next work can be started. In branch structure, if at least one of the things is done, the next work outside of the structure can be done. Given that the composite web service is composed of these four structures, QoS of composite web service can be obtained using calculations corresponding to the structure by the formula (2) [24]. Web service composition algorithm based on QoS shown in Algorithm 2.

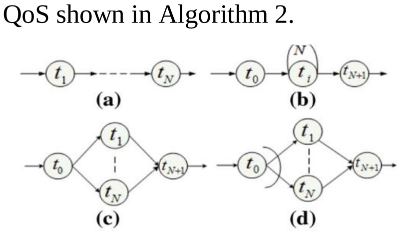

Fig. 10. basic composite models of composite service

Algorithm 2: QoS aware web service composition algorithm (UR(,QWV,),RSLi)

Begin

(1)Rank Services
(1.1) Compute QWV for each task t_i in T
(1.2)Save the RSL_i For each task t_i in T
(2)Store each RSL_i in task tables
(3)Compute Service Composition (SC) table
(3.1)Generate all possible Composition plans by taking Cartesian product of all the Task tables obtained in Step (2)
(3.2)Save the Composition plans (CP) in Service Composition Table
(4)Calculate QoS Aggregated value for each CP in Service Composition and save in
Composition Plan List (CPL)
(5)Constraint Analyzer
(5.1)Perform Constraint Analyzer (SC, C) for each CP in CPL
(5.2)Save composite services that satisfy constraints in Filtered Composition Plan List (FCP)
(6)Pareto Optimal based Selection
(6.1)Perform Pareto Selection (FCP)
(6.2)Save Composition Plans at eriltering in Pareto Optimal based Selected List (POSL)
(7)Compute Aggregated QoS Rank for each CP in POSL
(7.1)Evaluate all the Rank for each CP in POSL
(7.2)Save the CP with Rank in POSL
(8)Calculate Final rank (POSL,QWV)
(8.1)Compute Final rank for all CP in POSL
(8.2)Sort and save the Composition Plan in Ranked Composition Plan List (RCPL) Based on Final Rank
(9)Execute all the Composition Plan in RCPL
(10)Get feedback and up date Rep()
End

$$Time = \begin{cases} \sum_{i=1}^{N} T_i\,(a) \\ \sum_{i=1}^{N} T_i\,\,(b) \\ \max T_i\,\,(c) \\ \min T_i\,(d) \end{cases} \quad Cost = \begin{cases} \sum_{i=1}^{N} C_i\,(a) \\ \sum_{i=1}^{N} C_i\,\,(b) \\ \sum_{i=1}^{N} C_i\,(c) \\ \min C_i\,(d) \end{cases} \qquad (2)$$

IV. Application Case: Curriculum

A curriculum scenario is a sample of the system composed of service combination. For implementing curriculum in a semester, selection of instructors, their working days, selection of needed courses, and class selection are among services, combination of which is one of the issues which yet there is no automatic comprehensive solution that QoS features are applied in service selection. User demand includes a set of

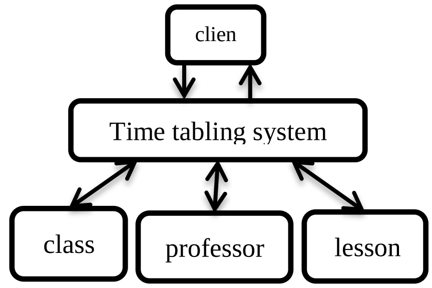

Fig. 11. time tabling scenario

works like class reservation, instructor reservation, and course selection. Atomic services (instructor, class, and course) should be selected in such a way that the best combination is obtained. Users can enter type of service and constraints and specific conditions and local constrains like QoS (QWV) setting in the form of demand as RFC standard. QoS weights are used in ranking services and play effective role in the process of constructing optimal composite web service in fitness function for genetic algorithm process. When user demand is entered into the system (RFC), firstly sub-domain of services is selected and then respective candidate services are chosen for doing works. These sub-domains are done by grouping agent considering expertise of instructors and their field and faculties, location of classes, and courses for the semester.

For combination generation, raking services is done using values of QWV and QF. User idea of QWV and system evaluation of QF services play key role in selection of optimal combination. Following ranking, genetic algorithm selects the best existing combination with imposing fitness function (formula 2), and manager agent and service agent and compositor agent are responsible for running this combination. Following retrieval of respective services and running process, QF values are updated by registry agent, and this memory will be contribute in subsequent runs in ranking services. Recording experience of each run increases system efficiency in subsequent runs.

$$fitness\ Function = \frac{\sum_{i=1}^{k} QF_i * QWVi}{k} \qquad (2)$$

User demand is firstly turned to triple by application interface agent. In this ordered triple (T, QWV, C) RFC, works include selection of respective course in specified time with selection of instructor and class. In QWV, weigh vector of qualitative features of user priorities are specified in multi-criteria decision, which is implemented by optimization, and conditions and constraints of user are stated in C form, which can choose out of 10 available conditions. Services in each university are prepared in a table in Excel environment along with qualitative features as manual by the education responsible person, part of which is shown in Table 2. Information related to QoS is constantly evaluated and updated by evaluator which is education CEO, and they are accessible in features depository. Combination program is updated in solution depository at every run periodically, and it is removed if necessary. Service providers register services available in service registry and their qualitative features are updated dynamically in the framework.

Framework evaluation environment is composed of three virtual machines. Service exploration and service ranking as well as construction of composite web services is done in a system with following characteristics: 3 GB RAM, Windows XP3, 2.13 GHz, CPU 3 Intel Core i. Clients, which are made by application interface in technical, literature and veterinary faculties and are responsible for service registry construction, have following characteristics: RAM 2 GB and Windows 7 ,2GHz, Duo CPU, 2Intel Core. Information related service providers and information related to service quality and actually service quality depository and solution depository and service depository are embedded in virtual machine with following characteristics: Windows XP, 3GBRAM and 3GHz, 2.13 CPU, Intel Core i.

In optimization and optimal composite web service construction part, MATLAB programming language is used for applying genetic algorithm. For each service in this application case, compliance between instructor expertise and respective course and the costs parameters are also especially considered in addition to other qualitative features of services, which are used in calculation of final compliance function. One of the parameters considered in this case, is the time needed for performing curriculum by system.

TABLE II. EXAMPLES OF SERVICES AVAILABLE INCLUDING CLASSES, LESSONS AND MASTER

Amount hour/	Specialty Code	master code	master	row
25000	12	91253	Dr.Khalilian	1
32000	8	45871	Dr.Nikravan	2
28000	11	52489	Dr.Pishvayi	3
15000	9	54219	Dr.shemirani	4
30000	11	36542	Dr.salajeghe	5

hour/ Amount	Class location	Class code	row
5000	2	154	1
4000	3	147	2
5000	2	123	3
3000	1	187	4
6000	3	132	5
2500	1	23	6
5500	5	352	7

Specialty Code	Amount hour/	Lesson code	row
12	38000	302	1
8 , 11	58000	305	2
8	45000	132	3
9	87000	845	4
11	25000	251	5
8	30000	265	6
12	4000	245	7

TABLE III. GENETIC ALGORITHM PARAMETERS

number of population	max of iteration	percent of crossover	percent of mutation
100	1000	0.01	0.99

Genetic algorithm parameters are set according to following table and obtained results are used at every run in simulation environment.

Finally, the proposed framework is simulated using Arena software, Version 13.50 on Islamic Azad University system, Karaj Branch with following characteristics: 3GB RAM 2.13 GHz (CPU Intel Corei3). Overall form of simulated framework is shown in Fig 12. This simulation is evaluated in five steps. In the first step, framework responds to 27 demands of users. In the next step, 45 user demands and after in last step 60, 75, 90 user demands are evaluate. Evaluation showed that with increasing user demands and updating internal system values, framework memory and optimizations by genetic algorithm considerably help reducing system response time and costs including computational costs and service use cost.

V. CONCLUSION

Proposed framework is provided with considering challenges existing in management of service-oriented architecture processes. Service-oriented architecture processes management is classified into service-oriented architecture lifecycle management, service management, service change management, service composition management and service interaction management, service records and exploration management. In this framework, service-oriented architecture processes are regularly structured and management of each part is done considering its performance.

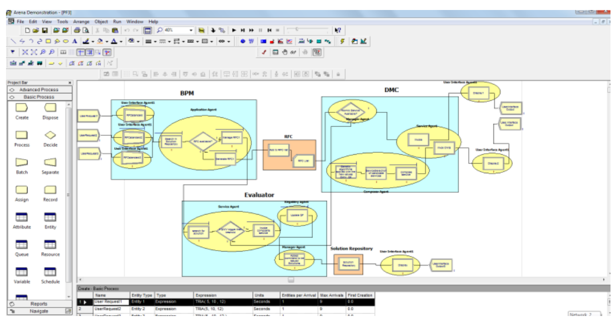

Fig. 12. Simulated framework in arena

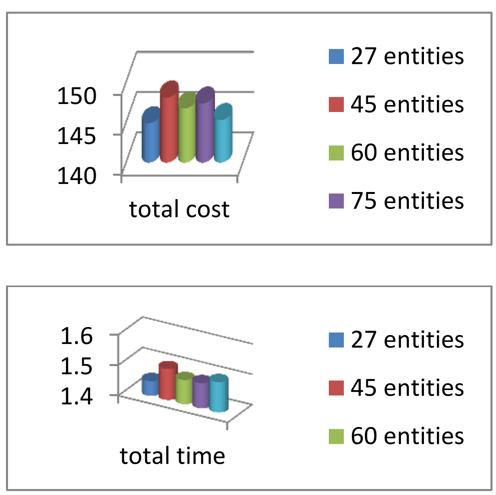

Fig. 13. Two-parameter simulation results show that with increasing time and cost of implementation of the framework increases system performance

As mentioned, focused processes have problems in scaling and run and strength. In focused processing, the processor should have the whole problem knowledge and can manage integrated knowledge and utilize it. Management and processing such knowledge needs high computational power and it is beyond capacity of a single focused system.

Thus, in this framework, multi-agent system is used for distributing the processing to improve service-oriented architecture processes. Depositories of this framework as its internal memory increase system computational power in consecutive runs and improves responding speed. For evaluating proposed framework, service combination is used. Curriculum system of Islamic Azad University, Karaj Branch, was used as application case by the proposed framework and it was tested. Results show that using this framework increase system speed and efficiency after pilot period in stabilization period. The more user demands are met by more works and more services are needed in combination, efficiency of proposed framework is shown more. Cost and time of responding and system availability and efficiency are among parameters which were evaluated. In future works, it is attempted to use BPM component in fuzzy system and then framework will be evaluated by standard databases like WS-Challenge database. Using semantic will be also among future works.

References

[1] T. Erl, "Service-oriented architecture (SOA): concepts, technology, and design," 2005.

[2] J. El Hadad, M. Manouvrier, and M. Rukoz, "TQoS: Transactional and QoS-aware selection algorithm for automatic Web service composition," Services Computing, IEEE Transactions on, vol. 3, pp. 73-85, 2010.

[3] R. Berbner, M. Spahn, N. Repp, O. Heckmann, and R. Steinmetz, "Heuristics for qos-aware web service composition," in Web Services, 2006. ICWS'06. International Conference on, 2006, pp. 72-82.

[4] E. Goncalves da Silva, L. Ferreira Pires, and M. van Sinderen, "Supporting dynamic service composition at runtime based on end-user requirements," 2009.

[5] M. Rambold, H. Kasinger, F. Lautenbacher, and B. Bauer, "Towards autonomic service discovery a survey and comparison," in Services Computing, 2009. SCC'09. IEEE International Conference on, 2009, pp. 192-201.

[6] Z. Li and L. O'Brien, "Towards effort estimation for web service compositions using classification matrix," International Journal on Advances in Internet Technology Volume 3, Number 3 & 4, 2010, 2010.

[7] D. Mallayya, B. Ramachandran, and S. Viswanathan, "An Automatic Web Service Composition Framework Using QoS-Based Web Service Ranking Algorithm," The Scientific World Journal, vol. 2015, 2015.

[8] W. Gaaloul, S. Bhiri, and M. Rouached, "Event-based design and runtime verification of composite service transactional behavior," Services Computing, IEEE Transactions on, vol. 3, pp. 32-45, 2010.

[9] F. Gao, E. Curry, M. I. Ali, S. Bhiri, and A. Mileo, "Qos-aware complex event service composition and optimization using genetic algorithms," in Service-Oriented Computing, ed: Springer, 2014, pp. 386-393.

[10] V. Cardellini, E. Casalicchio, V. Grassi, F. Lo Presti, and R. Mirandola, "Qos-driven runtime adaptation of service oriented architectures," in Proceedings of the the 7th joint meeting of the European software engineering conference and the ACM SIGSOFT symposium on The foundations of software engineering, 2009, pp. 131-140.

[11] C. Jatoth, G. Gangadharan, and R. Buyya, "Computational Intelligence based QoS-aware Web Service Composition: A Systematic Literature Review."

[12] M. Vallée, F. Ramparany, and L. Vercouter, "A multi-agent system for dynamic service composition in ambient intelligence environments," in The 3rd International Conference on Pervasive Computing (PERVASIVE 2005), 2005, pp. 165-171.

[13] Z. Huang, J. Zhang, and Q. Cong, "Agent-Based Service-Oriented Dynamic Integration ERP Architecture," in The Second International Symposium on Networking and Network Security (ISNNS 2010), 2010, p. 136.

[14] L. G. Nardin, A. A. Brandão, and J. S. Sichman, "Experiments on semantic interoperability of agent reputation models using the SOARI architecture," Engineering Applications of Artificial Intelligence, vol. 24, pp. 1461-1471, 2011.

[15] J. Li, D. Ma, L. Li, and H. Zhu, "AADSS: Agent-based adaptive dynamic semantic web service selection," in Next Generation Web Services Practices, 2008. NWESP'08. 4th International Conference on, 2008, pp. 83-89.

[16] H. K. Dam and A. Ghose, "Supporting change propagation in the maintenance and evolution of service-oriented architectures," in Software Engineering Conference (APSEC), 2010 17th Asia Pacific, 2010, pp. 156-165.

[17] Y.-Y. Fanjiang, Y. Syu, C.-H. Wu, J.-Y. Kuo, and S.-P. Ma, "Genetic algorithm for QoS-aware dynamic web services composition," in Machine Learning and Cybernetics (ICMLC), 2010 International Conference on, 2010, pp. 3246-3251.

[18] A. V. Dastjerdi and R. Buyya, "A taxonomy of qos management and service selection methodologies for cloud computing," Cloud Computing: Methodology, Systems, and Applications, pp. 109-131, 2011.

[19] M. Mohammed, M. A. Chikh, and H. Fethallah, "QoS-aware web service selection based on harmony search," in ISKO-Maghreb: Concepts and Tools for knowledge Management (ISKO-Maghreb), 2014 4th International Symposium, 2014, pp. 1-6.

[20] D. Wang, H. Huang, and C. Xie, "A Novel Adaptive Web Service Selection Algorithm Based on Ant Colony Optimization for Dynamic Web Service Composition," in Algorithms and Architectures for Parallel Processing, ed: Springer, 2014, pp. 391-399.

[21] X. Wang, Z. Wang, and X. Xu, "An Improved Artificial Bee Colony Approach to QoS-Aware Service Selection," in Web Services (ICWS), 2013 IEEE 20th International Conference on, 2013, pp. 395-402.

[22] T. Zhang, "QoS-aware Web Service Selection based on Particle Swarm Optimization," Journal of Networks, vol. 9, pp. 565-570, 2014.

[23] V. S. Jeure and Y. Kulkarni, "Approaches for Web Service Selection," 2014.

[24] X. Zhao, Z. Wen, and X. Li, "QoS-aware web service selection with negative selection algorithm," Knowledge and Information Systems, vol. 40, pp. 349-373, 2014.

[25] M. Fahad, N. Moalla, and Y. Ourzout, "Dynamic Execution of a Business Process via Web Service Selection and Orchestration," Procedia Computer Science, vol. 51, pp. 1655-1664, 2015.

[26] C. I. Pinzón, J. F. De Paz, D. I. Tapia, J. Bajo, and J. M. Corchado, "Improving the security level of the FUSION@ multi-agent architecture," Expert Systems with Applications, vol. 39, pp. 7536-7545, 2012.

[27] T. O. Group, "SOA Reference Architecture," 2011.

[28] L.-J. Zhang and J. Zhang, "SOA reference architecture," Web services research for emerging applications: Discoveries and trends, Information Science Reference, pp. 1-15, 2010.

[29] Y.-Y. FanJiang and Y. Syu, "Semantic-based automatic service composition with functional and non-functional requirements in design time: A genetic algorithm approach," Information and Software Technology, vol. 56, pp. 352-373, 2014.

[30] W. Wang, Q. Sun, X. Zhao, and F. Yang, "An improved particle swarm optimization algorithm for QoS-aware web service selection in service oriented communication," International Journal of Computational Intelligence Systems, vol. 3, pp. 18-30, 2010.

Modeling Access Control Policy of a Social Network

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***Abstract*—Social networks bring together users in a virtual platform and offer them the ability to share -within the Community- personal and professional information's, photos, etc. which are sometimes sensitive. Although, the majority of these networks provide access control mechanisms to their users (to manage who accesses to which information), privacy settings are limited and do not respond to all users' needs. Hence, the published information remain all vulnerable to illegal access. In this paper, the access control policy of the social network "Facebook" is analyzed in a profound way by starting with its modeling with "Organization Role Based Access Control" model, and moving to the simulation of the policy with an appropriate simulator to test the coherence aspect, and ending with a discussion of analysis results which shows the gap between access control management options offered by Facebook and the real requirements of users in the same context. Extracted conclusions prove the need of developing a new access control model that meets most of these requirements, which will be the subject of a forthcoming work.**

***Keywords*—social network; Facebook; access control; OrBAC; study of coherence**

I. Introduction

Facebook [1] is an online social network, free and very popular (1.65 billion users in 2016) allowing anyone to register, invite friends, exchange messages; share photos and videos, etc. After registration, the user owns an account that consists of a profile (personal information, professional information, photos, etc.) and a wall, which is powered by publications of friends, pages, groups and advertisers [2]–[4]. These publications can be a text, a photo or a video.

Facebook was invented by "Marc Zuckerburg" in 2004 in order to share information between Harvard University students and was put to use of the public on September 2006 [5]. Since then, it continues to expand to attract the largest number of users and offers them the means to manage access to their informations from the "Privacy Settings" interface. Yet, it is often the subject of debate [3], [4], [6]–[8], because of privacy issues that remains .That lead us to closely analyze this problematic using an access control model allowing the extracting of incoherence problems that exist in Facebook Access control policy to subsequently propose the most appropriate access management solution to resources .

Conventional access control models: Discretionary Access Control (DAC), Mandatory Access Control (MAC) [9], [10]. Role Based Access Control (RBAC) [9]–[11], and others are not suitable to the needs and requirements of social networks since they are often limited to the definition of positive permissions and cannot be used as part of a system that are no more interested in the permissions' definition than to prohibition's especially if it is contextual privileges (access rules based on conditions) [2]. Therefore, it is interesting to use the model: Organization Role Based Access Control (OrBAC) [9] ; This is an access control model focused on the organization and based on first-order logic. It meets all the previously mentioned requirements and adapts perfectly to the context of Facebook. Thanks to OrBAC, friends can be structured by role (friends, friends of friends, family, etc.), actions can be classified by activities (display, publish, etc.) And account owner's data can also be arranged by views (personal information, photos, etc.) [2].

Before suggesting the OrBAC's extension adapted to Facebook, it is essential to assimilate the use of Facebook and master its access control policy to clearly define the problem. In the same logic, this work is focused on the modeling and simulation of the entire policy as it is with the OrBAC model and MotOrBAC [12], software to edit all of the incoherencies detected in the policy, in addition, what the policy offers to the user as access control management features and the user's needs are compared in order to provide a more appropriate access control model using OrBAC and defining contextual rules to manage the policy of a finer way; This will be the subject of my forthcoming work.

II. A Review of Related Works

Few studies have focused on the problem of access control in the context of Facebook. Madejski, Johson and Belovin [13] and Brown, Hewe, Ihbe, Prakash and Borders [14]; used survey to study the main cause of access rights' violations. The results show that access control issues are due to the inability of proper management of privacy settings by the user. Therefore the proposed solution is recommending defensive strategies centered on the user. Masoumzadeh and Joshi [15], made the investigation based on the human aspect, they specifies that the conflicts of the access control policy are related to users owners of a same information, one of them wants to hide it and the other wants to publicize it. The solution was to suggest countermeasures implementation-wise and behavior-wise of the user. However, Yamada, Kim and Perrig [16], and Cheek and Shehab [17], specified that it is the implementation that must be developed to solve access control's problem. Toufik, Cousin, and Cuppens [2], proposed an OrBAC extension to control access into the Facebook context.

III. Preliminaries: Presentation of OrBAC

OrBAC [9], is an access control model based on the organization, using the first-order logic to define relations between entities and access control policy. That policy is defined on two levels; the abstract one (role, activity, view) and the concrete one (subject, action, object).

A group of active entities is called "organization", each one playing a role within that organization. Therefore, each organization empowers subjects in roles. For example, the organization "faculty" may empower "Mary" in the role of "student". The concept of "role" enables dynamic management of security policy as long as the addition or deletion of a subject does not require a complete change of policy because it's only one relation that will be deleted (relation between this subject and the role). The notation is as following, if org is an organization, s is a subject and r is a role, then Empower (org, s, r) means that org empowers subject s to play the role r.

Every organization has objects representing passive entities. In order to structure the 'objects' entities satisfying a common property, and facilitate the management as mentioned previously, the entity "view" is used. Taking the example of the faculty, the view can for example be "course files", the objects will therefore be "computer courses, English courses, etc". The relation between the two entities is: If org is an organization, o is an object and v is a view, then Use (org, o, v) means that org uses object o in view v.

The entities "actions" define the way in which the subjects access to objects, it can be for example access to reading, writing, etc. The structuring of these entities is called "activities". The same activity can correspond to several actions in different organizations. The relation linking these entities is: If org is an organization, a is an action and a is an activity, then Consider (org, a, a) means that the organization org considers the action a as part of the activity a.

OrBAC also allows activation and deactivation of security rules based on concrete conditions of access called "contexts". Different types of situations exist: default context, temporal contexts, spatial contexts, composed contexts, etc. The used relation is: If org is an organization, s is a subject, a is an action, o is an object and c is a context, then Define (org, s, a, o, c) means that within the organization org, context c is true between subject s, the object o and action a. The context can be for example: Define (Faculty, John, consult, doc1, working_hours) that means that John can see the doc1 only during working hours.

The OrBAC access control policy is defined afterwards based on abstract level entities and presented relations. It consists of permissions, prohibitions, obligations and recommendations linking entities at the abstract level.

Notation is as follows: If org is an organization, r is a role, a is an activity and v is a view, then Permission (org, r, a, v, c) means that organization org allows role r to perform an activity on the view v in the context c.

The transition to the concrete level is done automatically afterwards: if s is a subject, a is an action and o is an object, then Is_permitted(s, a, o) means that the subject s has the permission to perform the action a on the object o. Other privileges Is_prohibited, Is_obligatory, and Is _recommended are defined in the same way.

OrBAC also offers the possibility to simulate and analyze security policies using the MotOrBAC simulator.

IV. Modeling and Simulation of Facebook Access Control Policy

This section presents the modeling of the security policy suggested by Facebook using OrBAC and subsequently the simulation of this policy using MotOrBAC simulator as follows:

Algorithm

Input: Facebook entities and access rules.

Output: security policy incoherencies.

Method:

1) Modeling of security policy with the OrBAC model:

- Inventory of roles (Friends, Family, etc.).
- Inventory of activities (create, consult, etc.).
- Inventory of views (personal_infos, etc.).
- Inventory of access rights (permissions).

2) Simulation of security policy with MotOrBAC simulator :

- Creating organizations (Facebook, U1, etc.).
- Adding of abstract entities (roles, activities, views).
- Adding of concrete entities (subjects, actions, objects).
- Adding of access rights.
- Simulation: Detection of conflicts.

A. The organization

The "Facebook" organization is defined as a central organization, "Users" as a sub-organization of Facebook, and users (accounts' owners) 1, 2, 3 and 4 as sub-organizations of "Users" (Fig. 1).

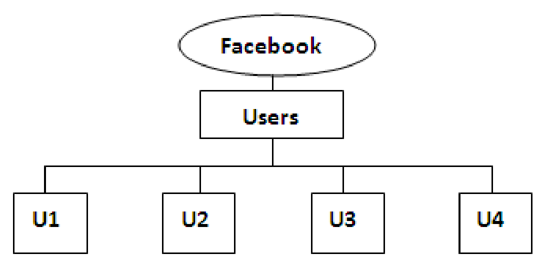


Fig. 1. The hierarchy of organizations

B. Subjects and roles

Roles are defined (what's written in black) at the central organization "Facebook" (Fig.2.), so they can be used by all users (principle of hierarchy). Among the "users" organizations, the organization "U1" is taking as an example, it empowers subjects (what's written in green) in roles that are classified as friends, family, study, etc. The diagram below summarizes all the roles and their hierarchy; associated with subjects. The relation "empower" should be defined for all subjects and roles. Here is an example: Empower (U1, Alexander, public).

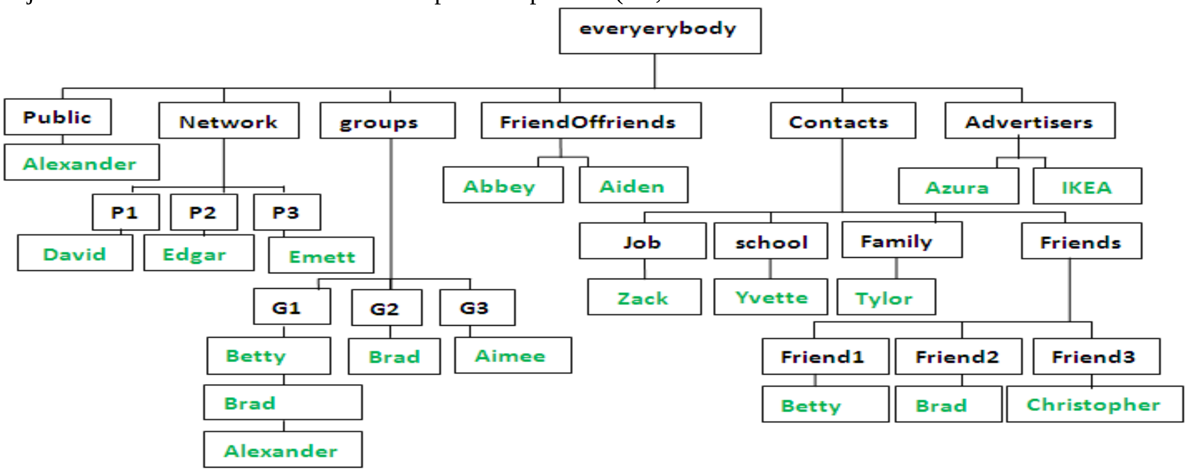


Fig. 2. The hierarchy of roles

C. *Activities and actions*

Every user in Facebook owns resources (photos, videos, etc.) and is permitted to control the access to these regarding members (friends, etc). Members perform actions like checking his pictures, etc. These actions can be structured in activities, the whole of it is presented in the Table below (TABLE I.):

- The activity "create" for example is an abstraction of the action 'open'.
- "Act.delete" and "modify" are sub-activities of "Act.manage" and associated respectively to actions "remove" and "change".

The relations "consider" has to be defined between all the activities and the actions. For instance: Consider (Facebook, create, open).

TABLE I. THE HIERARCHY OF ACTIVITIES

Activity	Sub-activities	Actions
	Create	Open.
	Consult	View, search, read, see.
Activity	Control_ Access ├-control_users_Access └-control_Face_Access	Allow, oblige, prohibit.
	Publish └-Publish_inmywall	Share, illustrate.
	Act.manage ├-Act.delete └-modify	 Remove. Change.
	Organize	Conduct.
	Criticize ├Comment └like	 State_opinion. Please.
	compose	Write, introduce.
	Use	Copy, store, archive.
	contact	Send_msg.
	Invite	Add.
	Join	Belong_to.
	Examine	Test.
	Block	Suspend.
	Accept	Approve.

D. *Activities and Actions*

In an account, many components exist (TABLE II.); photos, videos, personal informations, etc.

The relation between views and objects is defined as following: Use (Facebook, chaimaabelbergui, Full_name).

TABLE II. THE HIERARCHY OF VIEWS

View	Sub-views	Objects
Account (My_account)	About	
	○ Personal_infos	
	▪ Full_name	Chaimaa Belbergui
	▪ gender	Female
	▪ birth_date	March
	▪ family.situation	single
	▪ political_opinions	nothing to report
	○ Professional_infos	
	▪ Schooling	PhD student
	▪ Professional_skills	Nothing to report
	▪ work	Nothing to report
	○ View_Contact	
	▪ Mobile_phone	Number
	▪ Email	Email_address
	▪ Address	streetx
	▪ website	site
	Parameters	friendRequests.Para notif.Para pub.Para app.Para profile.Para
	Favourites	
	○ Publications	
	▪ Photos	
	-Photo_page	Photo1_page, photo2_page
	-Photos_account	
	Profile_photo	P_photo
	Cover_photo	C_photo
	Wall_photos	Wall_photo1, wall_photo2
	▪ Videos	Vidéo1, vidéo2
	▪ Status	Statut1, statut2
	▪ Comments	Comment1, comment2
	○ Wall	Journal_Users
	○ Messages	Message1, message2
	○ Friendrequests	
	▪ friendsOffriends_R	R_friend_offriends
	▪ public_R	
	○ Event	Conference, travel.
	○ Identifications	
	▪ Photos_identif	Identif_photo1, identif_photo2
	▪ Status_identif	Identif_statut1, identif_statut2
	▪ Videos_identif	Identif_vidéo1, identif_vidéo2
	○ Likes	like1, like2
	○ Relationships	
	▪ RelationU1_U4	
	○ pages	friend Moroccan_cuisine
	Indentifiants	
	○ login	Pseudo
	○ password	Pseudo
Groups		Group1, Group2

E. *Access control policy*

In this section access rights that Facebook (Face) gives to users and also those given by the account's owner to friends, family, etc. are detailed. The privileges are modeled next by OrBAC model.

- Facebook-User policy

Each person is permitted by Facebook to register; but before, he should choose and type his identifiants and some informations like : full name, gender, age, etc. By having an account, the user can exchange messages with friends, publish photos and videos, join groups, create events, etc.

Publications can be managed by the owner, or consulted and criticized by other persons belonging to Facebook.

When some users signal an account, this one cannot more be managed by owner. Facebook delete it automatically.

Here is Access rights:

Permission (Face,Userss,create, account)

Obligation (Face,Users,compose,identifiants)

Obligation (Face,Users,compose,About)

Permission (Face,Users,consult, About)

Permission (Face,Users, Act.manage, About)

Permission (Face,Users, Act.manage, identifiants)

Permission (Face,Users, Act.manage, parameters)

Permission (Face,Users, Act.manage, publications)

Permission (Face,Users, Act.manage, wall)

Permission (Face,Users, Act.manage, message)

Permission (Face,Users, Act.manage, identifiants)

Permission (Face,Users, criticize, publications)

Permission (Face,Users, criticize, wall)

Permission (Face,Users, criticize,events)

Permission (Face,Users, criticize, pages)

Permission (Face,Users, contact, account)

Permission (Face,Users, inviter, account)

Permission (Face,Users, adhérer, Groups)

Permission (Face,Users, publish, publications)

Permission (Face,Users, examine, identifications)

Permission (Face,Users, Accesscontrol, infosperso)

Permission (Face,Users, Accesscontrol, infospro)

Permission (Face,Users,Accesscontrol,viewcontact)

Permission (Face,Users, Accesscontrol,publications)

Permission (Face,Users, Accesscontrol, wall)

Permission (Face,Users, create, pages)

Permission (Face,Users, Act.manage, pages)

Permission (Face,Users, consult, pages)

Permission (Face,Users, accept, friend_requests)

Permission (Face,Users, block, account)

Permission (Face,Users, block, messages)

Permission (Face,Users, block, friend_requests)

Permission (Face,Users, block, events)

Permission (Face,Users, block, pages)

Permission (Face,Users, organize, applications)

Permission (Face,Users, organize, events)

Prohibition(Face,P1,comment,photosmypage)

Permission (Face, P1, comment, photos)

Permission(Face,advertisers,publishinmywall, publications)

Permission (Facebook,G3,consult, account)

Prohibition(Face,P1,Face_AccessControl, publications)

Permission(Face,P1,AccessControl, friend_requests)

Prohibition(Face,P3,AccessControl,profile_photo)

Permission(Face,P3,AccessControl, photos)

Prohibition(Face,P1,Face_AccessControl, publications)

Permission(Face,P1,AccessControl,publications)

Permission(Face,P2, consult, photos_account)

Permission(Face,friend3,publishinmywall,comment)

Prohibition(Facebook,P1,Act.manage,account, signaled_account)

Permission (Facebook,P1,Act.manage, account)

- User-User policy

Each user can manage access to his publications and informations. He can permit or prohibit access to friends, family, public,etc. As follows :

Permission (U1, friends, consult,publications)

Permission (U1, friends, consult, events)

Interdiction (U1, public, consult, publications)

Interdiction (U1, public, consult, events)

Permission (U1, friendOffriend, contact, account)

Interdiction (U1, public, contact, account)

Permission (U1, friends, consult, wall)

Interdiction (U1, public, consult, wall)

Permission (U1, friends, publish, wall)

Interdiction (U1, public, consult, identifications)

Interdiction (U1, friends, consult,personal_infos)

Permission (U1, friends, consult, pages)

Permission (U1, friends, criticize, publications)

Permission (U1, friends, criticize, wall)

Permission (U1, friends, criticize, events)

Prohibition (U1,everybody,consult,relation U1_U4)

Prohibition (U1, friend1, consult, photos)

Permission (U1, G1, consult, photos)

Prohibition (U1, G2, consult, photos)

Permission (U1, G1, consult, photos)

Prohibition(U1,public,consult, photos_account)

Prohibition(U1,P2,consult, photos_account)

Prohibition(U1,friend3,publishinmywall publications)

Prohibition(U1,advertisers,publishinmywall, publications)

Prohibition(U1,public,consult, account)

Permission (U4,everybody,consult,relation U1_U4)

Permission(U2,public, consult, photos_account) .

F. Simulation

The central organization and the sub-organizations are created (Fig.3).Then, all of the abstract entities in the Facebook organization are defined, beginning by roles (Fig.4). The concrete entities are specified in the organization U1 and assigned to the abstract ones. The figure (fig.5.) gives an example of this assignment linking the subjects and the roles. Finally the context "signaled account" is defined (Fig.6.) on which Facebook is based on to delete an account.

Fig. 3. The definition of organizations

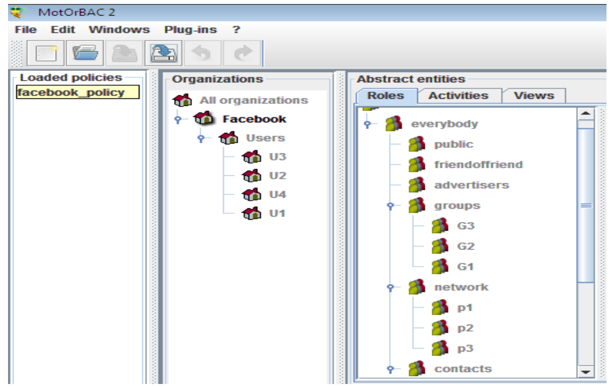


Fig. 4. The definition of roles

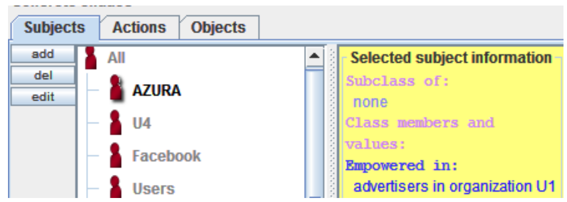
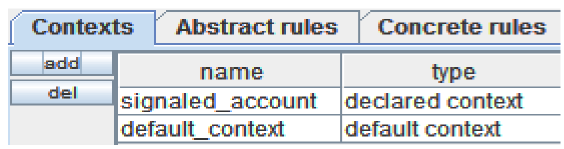
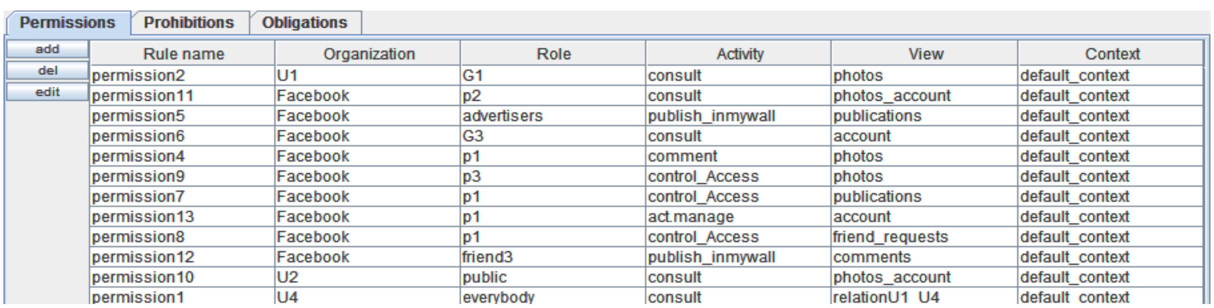


Fig. 5. The definition of subjects and their association to roles



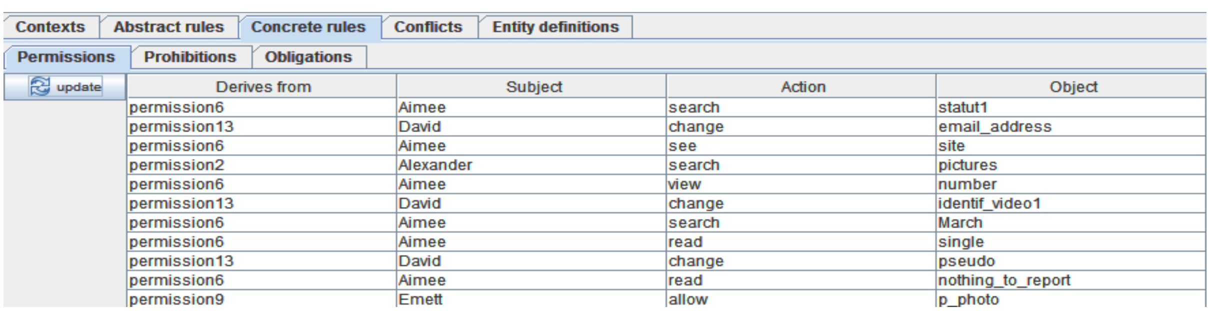
name	type
signaled_account	declared context
default_context	default context

Fig. 6. The definition of the context



Rule name	Organization	Role	Activity	View	Context
permission2	U1	G1	consult	photos	default_context
permission11	Facebook	p2	consult	photos_account	default_context
permission5	Facebook	advertisers	publish_inmywall	publications	default_context
permission6	Facebook	G3	consult	account	default_context
permission4	Facebook	p1	comment	photos	default_context
permission9	Facebook	p3	control_Access	photos	default_context
permission7	Facebook	p1	control_Access	publications	default_context
permission13	Facebook	p1	act.manage	account	default_context
permission8	Facebook	p1	control_Access	friend_requests	default_context
permission12	Facebook	friend3	publish_inmywall	comments	default_context
permission10	U2	public	consult	photos_account	default_context
permission1	U4	everybody	consult	relationU1_U4	default_context

Fig. 7. The definition of permission at the abstract level



Derives from	Subject	Action	Object
permission6	Aimee	search	statut1
permission13	David	change	email_address
permission6	Aimee	see	site
permission2	Alexander	search	pictures
permission6	Aimee	view	number
permission13	David	change	identif_video1
permission6	Aimee	search	March
permission6	Aimee	read	single
permission13	David	change	pseudo
permission6	Aimee	read	nothing_to_report
permission9	Emett	allow	p_photo

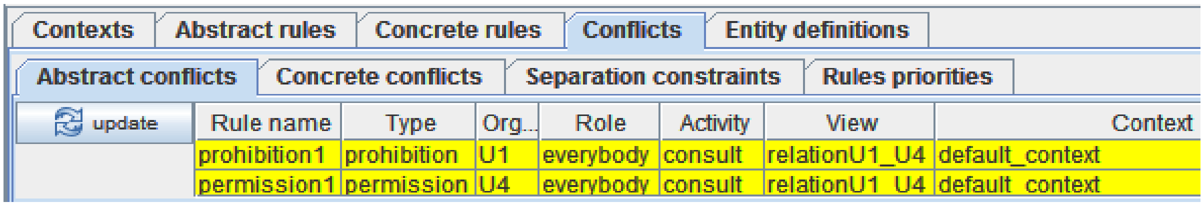
Fig. 8. The generation of permissions at the concrete level

The next step was to define all of the privileges in the abstract level: permissions, prohibitions and obligations that match to the policy of access control used by Facebook (Fig. 7). MotOrbac allows subsequently the automatic transition to the concrete level (Fig. 9) by the "update" tool.

- The detection of coherence

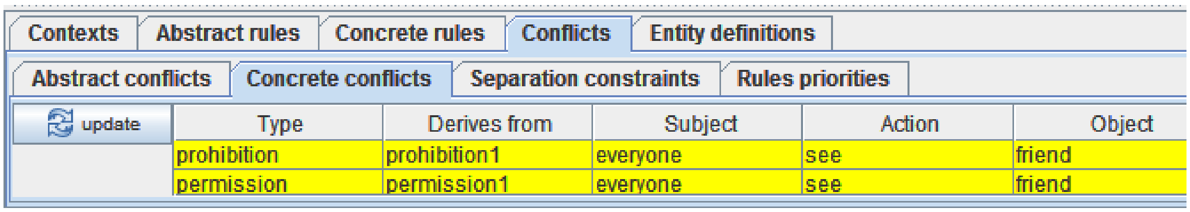
What is interesting about OrBAC is that it allows also to test the policy's coherence to count the conflicts in two levels; the abstract and concrete one.

Results show that 13 conflicts are present at the abstract level, which implies 122 at the concrete level. An example of the conflict is shown at the (Fig.9.) at the abstract level and it's translation to the concrete level (Fig.10.); the figure (Fig.11.) presents more examples of conflicts. By inadequacy of space, only some conflicts are presented.



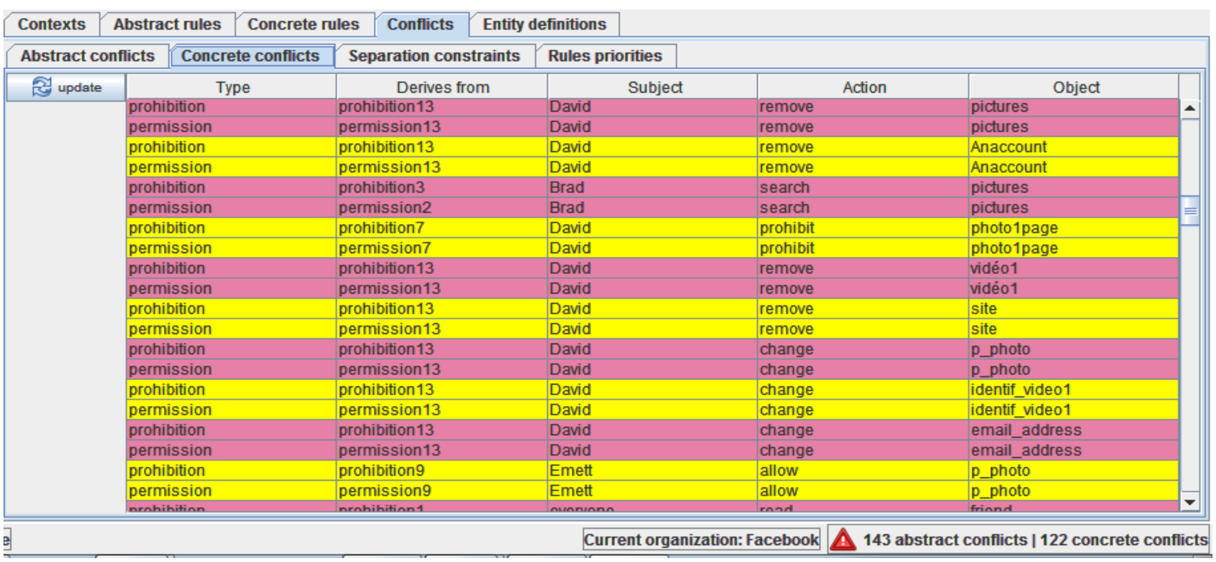
Rule name	Type	Org...	Role	Activity	View	Context
prohibition1	prohibition	U1	everybody	consult	relationU1_U4	default_context
permission1	permission	U4	everybody	consult	relationU1_U4	default_context

Fig. 9. Conflict's detection at the abstract level (between permission 1 and prohibition1)



Type	Derives from	Subject	Action	Object
prohibition	prohibition1	everyone	see	friend
permission	permission1	everyone	see	friend

Fig. 10. Conflict's detection at the concrete level (between permission 1 and prohibition1)



Type	Derives from	Subject	Action	Object
prohibition	prohibition13	David	remove	pictures
permission	permission13	David	remove	pictures
prohibition	prohibition13	David	remove	Anaccount
permission	permission13	David	remove	Anaccount
prohibition	prohibition3	Brad	search	pictures
permission	permission2	Brad	search	pictures
prohibition	prohibition7	David	prohibit	photo1page
permission	permission7	David	prohibit	photo1page
prohibition	prohibition13	David	remove	vidéo1
permission	permission13	David	remove	vidéo1
prohibition	prohibition13	David	remove	site
permission	permission13	David	remove	site
prohibition	prohibition13	David	change	p_photo
permission	permission13	David	change	p_photo
prohibition	prohibition13	David	change	identif_video1
permission	permission13	David	change	identif_video1
prohibition	prohibition13	David	change	email_address
permission	permission13	David	change	email_address
prohibition	prohibition9	Emett	allow	p_photo
permission	permission9	Emett	allow	p_photo
prohibition	prohibition1	everyone	read	friend

Fig. 11. Detection of conflicts at the concrete level

V. Discussion

The modeling and the simulation of the performed policy in the previous section confirm that the OrBAC model is very suitable to Facebook's context on the one hand, on the other hand they allowed to detail privileges given by Facebook to its users to be very detailed, and also those that every owner can give to his contacts, network, public, (Privacy settings) in order to correctly manage access to informations.

The most interesting is conflicts' analysis that allowed us to count coherence problems that exist in the access control policy defined by Facebook and which block the user to manage the entire privacy features. I sum them up in the following:

Conflicts between permissions and prohibitions defined by the two users:

- Coherence 1 between:

Prohibition (U1, everybody, consult, relation U1_U4)

Permission (U4, everybody, consult, relation U1_U4)

U1 and U4 are in friendship relation. When U1 prohibits to "everybody" to consult this relationship, while U4 allows them the access; that generates a conflict.

- Coherence10 between :

Prohibition (U1, public, consult, photos_account)

Permission (U2, public, consult, photos_account)

The access control to photos is limited because managing who copies them or shares them or even downloads them is impossible, that is why even if U1 does not allow the public to consult his photos, any friend can share them in public way.

Conflicts between permissions of Facebook and prohibitions of the user U1:

- Coherence 5 between :

Prohibition (U1,advertisers, publishinmywall, publications)

Permission(Face,advertisers,publishinmywall, publications)

Even if the user U1 chooses to not publish advertisements on his wall in privacy settings, Facebook obliges him to be contacted by advertisers.

- Coherence 6 between :

Prohibition (U1,public,consult, account)

Permission (Facebook, G3, consult, account)

Even though U1 chose not to be publicly listed in Facebook as soon as he join a group, all members of this group can view his profile and even see his account even if they are not members of his friends. In concrete level Aimee belongs to public, and both of them are members of group 3. Consequently, Facebook permit her to view U1 account.

- Coherence11 between :

Prohibition(U1,P2,consult, photos_account)

Permission(Face,P2, consult, photos_account)

Limiting access control to photos is a main cause of this incoherence. When U1 block someone (P2); Edgar in concrete level, U1 prohibit him to access his profile, his photos, his videos, etc. While, Facebook allows him to access them simply by typing "Photos of U1 full name" in the search bar.

- Coherence 12 between :

Prohibition (U1, friend3, publishinmywall, publications)

Permission (Face, friend3, publishinmywall, comment)

Even if U1 prohibit his friend3; Christopher in concrete level, from posting on his wall, there is another way to do it; it's to post it in a comment. Facebook does not give users the ability to manage "Likes" and "comments" on their publications.

Conflicts between permissions and prohibitions assigned by Facebook to users:

- Coherence 4 between :

Prohibition (Face, P1, comment, photosmypage)

Permission (Face, P1, comment, photos)

Facebook permit P1; David in concrete level, to comment on all his photos and prohibit him to comment it on his page. Actually, when P1 comments a post on his page he does it as a page, not as a person.

- Coherence 7 between :

Prohibition (Face, P1, Face_AccessControl, publications)

Permission (Face, P1, AccessControl, publications)

Facebook allows users (P1 for example) to control access to all of their posts but prohibit them from managing them compared to Facebook.

- Coherence 8 between :

Prohibition(Face,P1,AccessControl, friendsOffriends_requests)

Permission (Face,P1,AccessControl, friend_requests)

Facebook allows users (P1 for example) to choose who can contact them, but forces them to be contacted by friends of friends; which explains the detected conflict.

- Coherence 9 between :

Prohibition (Face, P3,AccessControl, profile_photo)

Permission (Face, P3, AccessControl, photos)

In the same logic, Facebook allows users to control access on all photos, but doesn't give them the same right on the profile picture; it is always public.

- Coherence 13 between :

Prohibition(Facebook,P1,Act.manage,account, signaled_account)

Permission (Facebook, P1, Act.manage, account)

Facebook prohibits users in some cases (signaled account) to manage them accounts while they have the right to do it habitually; which generates a conflict.

Conflicts between permissions and prohibitions assigned to people by the owner of the account U1:

- coherence 2 between :

Prohibition (U1, friend1, consult, photos)

Permission (U1, G1, consult, photos)

When U1 prohibits a friend from viewing photos that he posts; the prohibition is not necessarily taken into account if this friend is a member of one of U1 groups. For example, in concrete level, Betty is prohibited to access to photos in friend context but permitted to do it in group context.

- coherence 3 between :

Prohibition (U1, G2, consult, photos)

Permission (U1, G1, consult, photos)

When U1 allows to the group1 the access to his photos and he prohibit it to group2 knowing that some persons belong to both of the groups that create a conflict; in concrete level Brad belongs to both groups one and two.

As can be seen; Facebook does not suggest any solution to the listed problems and does not meet the needs of users.

Thereby, it is essential to use an access control model more detailed allowing to meet users' requirements.

VI. Conclusion

It is indisputable that Facebook continues to expand in all directions. Even though, the management of access control is still very limited compared to the needs of users who often claim problems. This finding is based on modeling and simulation of the security policy adopted by Facebook which have made, these are based on the use of the OrBAC model and MotOrBAC software. To the best of our knowledge, there is the first work that analyses coherence aspect of Facebook security policy.

The conclusion is that several coherences exist in this policy. Also, privacy settings are limited, for example: When user likes the photo of x, it is impossible to prohibit friends of x to see this "like". It is also impossible to make comments from our friends and my family private. Also, user do not necessarily trust the members belonging to the same class (eg. friends) with the same degree. Therefore, they should not have the same privileges; which is impossible on Facebook. Thus, there is no means to manage in a finer way access to resources.

Our next target is to develop a more complete model, suitable to the context of Facebook without incoherencies and that meets most of the requirements expressed by users of this social network.

References

[1] A. F. J. G. M. à jour le 31/03/16 16:41, "Nombre d'utilisateurs de Facebook dans le monde." [Online]. Available: http://www.journaldunet.com/ebusiness/le-net/1125265-nombre-d-utilisateurs-de-facebook-dans-le-monde/. [Accessed: 29-May-2016].

[2] B. Toufik, M. E. Cousin, M. F. Cuppens, and M. N. Cuppens, Expression d'une politique de sécurité dans un réseau social, partie 2. Rapport de stage, Telecom Bretagne, 2010.

[3] M. Tremblay, M. Sc. , Analyse des impacts de la mondialisation sur la sécurité - Rapport 9, Septembre 2010

[4] B. Toufik, M. E. Cousin, M. F. Cuppens, and M. N. Cuppens, Expression d'une politique de sécurité dans un réseau social. Rapport de stage, Telecom Bretagne, 2010.

[5] "Facebook," Wikipédia. 29-May-2016.

[6] Y. Estienne, Un monde de verre: Facebook ou les paradoxes de la vie privée (sur) exposée. Lille, France: École supérieur de journalisme de Lille, 2011.

[7] T. Mendel, Étude mondiale sur le respect de la vie privée sur l'Internet et la liberté d'expression. Paris: Unesco, 2013.

[8] R. Ajami, N. Ramadan, N. Mohamed, and J. Al-Jaroodi, "Security challenges and approaches in online social networks: A survey," IJCSNS, vol. 11, no. 8, p. 1, 2011.

[9] A. A. El Kalam, R. El Baida, P. Balbiani, S. Benferhat, F. Cuppens, Y. Deswarte, A. Miege, C. Saurel, and G. Trouessin, "Or-BAC: un modele de contrôle d'acces basé sur les organisations," Cah. Francoph. Rech. En Sécurité L'information, vol. 1, pp. 30–43, 2003.

[10] D. F. Ferraiolo and D. R. Kuhn, "Role-based access controls," ArXiv Prepr. ArXiv09032171, 2009.

[11] D. Ferraiolo and D. Richard Kuhn, Role-based access control: features and motivations.Article, 1995.

[12] F. Autrel, F. Cuppens, N. Cuppens-Boulahia, and C. Coma, "MotOrBAC 2: a security policy tool," in 3rd Conference on Security in Network Architectures and Information Systems (SAR-SSI 2008), Loctudy, France, 2008, pp. 273–288.

[13] M. Madejski, M. Johnson, and S. M. Bellovin, "A study of privacy settings errors in an online social network," in Pervasive Computing and Communications Workshops (PERCOM Workshops), 2012 IEEE International Conference on, 2012, pp. 340–345.

[14] G. Brown, T. Howe, M. Ihbe, A. Prakash, and K. Borders, "Social networks and context-aware spam," in Proceedings of the 2008 ACM conference on Computer supported cooperative work, 2008, pp. 403–412.

[15] A. Masoumzadeh and J. Joshi, "Ontology-based access control for social network systems," Int. J. Inf. Priv. Secur. Integr., vol. 1, no. 1, pp. 59–78, 2011.

[16] A. Yamada, T. H.-J. Kim, and A. Perrig, "Exploiting privacy policy conflicts in online social networks," CMU-CyLab-12-005 Carnegie Mellon Univ., 2012.

[17] G. P. Cheek and M. Shehab, "Policy-by-example for online social networks," in Proceedings of the 17th ACM symposium on Access Control Models and Technologies, 2012, pp. 23–32.

BF-PSO-TS: Hybrid Heuristic Algorithms for Optimizing Task Schedulingon Cloud Computing Environment

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***Abstract*---Task Scheduling is a major problem in Cloud computing because the cloud provider has to serve many users. Also, a good scheduling algorithm helps in the proper and efficient utilization of the resources. So, task scheduling is considered as one of the major issues on the Cloud computing systems. The objective of this paper is to assign the tasks to multiple computing resources. Consequently, the total cost of execution is to be minimum and load to be shared between these computing resources. Therefore, two hybrid algorithms based on Particle Swarm Optimization (PSO) have been introduced to schedule the tasks; Best-Fit-PSO (BFPSO) and PSO-Tabu Search (PSOTS). According to BFPSO algorithm, Best-Fit (BF) algorithm has been merged into the PSO algorithm to improve the performance. The main principle of the modified BFSOP algorithm is that BF algorithm is used to generate the initial population of the standard PSO algorithm instead of being initiated randomly. According to the proposed PSOTS algorithm, the Tabu-Search (TS) has been used to improve the local research by avoiding the trap of the local optimality which could be occurred using the standard PSO algorithm. The two proposed algorithms (i.e., BFPSO and PSOTS) have been implemented using Cloudsim and evaluated comparing to the standard PSO algorithm using five problems with different number of independent tasks and resources. The performance parameters have been considered are the execution time (Makspan), cost, and resources utilization. The implementation results prove that the proposed hybrid algorithms (i.e., BFPSO, PSOTS) outperform the standard PSO algorithm.**

Keyword---Cloud computing; task scheduling; CloudSim; Particle Swarm Optimization; Tabu search; Best-Fit

I. Introduction

In recent years, there has been a rapid development of science and technology, including in computer science, where the development and modernization of the Cloud computing and Big Data in general service have been used[1]. So, this growth leads to more demand for this technology because of the different demands by the users with the evolution of the Web services, which provide the user with all the needed requirements and measuring anywhere and anytime (e.g., servers, storage, networks, operating systems). These services could be offered by Cloud computing[2].

Cloud computing fosters elasticity and seamless capability of interchanging the information and resources between the user and providers through the Internet. Therefore, Cloud computing can help enterprises to improve the creation and delivery of IT solutions by providing them with easy access to services in a cost effective and flexible manner. On the other hand, the Cloud computing applications span many levels, including business, technology, government, smart grids, intelligent transportation networks, disaster management, automation, and data analysis[3]. Cloud computing service providers make the large-scale network servers from the data center to be large-scale virtual resources. Infrastructure as a Service (IaaS) level is the delivery of hardware (e.g., storage and network), and associated software (OS, visualization technology, file system), and provide a lot of computational capacities to serve remote users in a flexible and efficient way. In this model, the resources are provisioned in the form of Virtual Machines (VMs) deployed within the Cloud equipment consisting of pooling data, physical resources etc. for fulfilling the requests. Therefore, resource management sub systems in the Heterogeneous Distributed Computing System (*HDCS*) are designed to schedule the incoming tasks in getting the service[4].

On the other hand, there are some challenges facing Cloud Computing. One of the major challenges is the task scheduler.

Task scheduling is the most important issue in the Cloud computing because the user will have to pay for using the resources on the basis of time. The goal of task scheduling is to distribute the load evenly in the system by maximizing resource utilization and reducing execution time.

Typically, the numbers of tasks and resources are tremendous in the Cloud computing environment, especially for big data applications. Therefore, some efforts have been made towards this issue. For instance, formulating the scheduling problem as a general task graph to be executed on different VMs to detract execution time and maximize the resource utilization, using heuristic algorithms [5].

Kennedy and Eberhart [6], have presented a self-adaptive global search-based optimization algorithm, called PSO, in terms of time and resources. The algorithm is similar to other population based algorithms as Genetic algorithm without direct recombination of individuals of the population. Instead, it relies on the social behavior of the particles. In every generation, each particle adjusts its trajectory based on its best position called (local best) and the position of the best particle called (global best) of the entire population. These concepts increase the random nature of the particle and converge quickly to a global minimum with a reasonable good solution. *PSO* algorithm has become popular because of its simplicity and its effectiveness in a wide range of applications. There are some applications that have used *PSO* algorithm to solve the NP-Hard problems like scheduling and allocation task problem, the data mining problem, and the environmental engineering problem[7].

In this paper, two hybrid heuristic algorithms, *BFPSO* and *PSOTS*, have been proposed to find a suitable task scheduling based on particle swarm algorithm in the Cloud computing environment. The main issues of these hybrid algorithms are reducing execution time (Makspan), reducing cost and maximizing resources utilization.

According to the first hybrid (*BFPSO*) algorithm, the BF algorithm has been merged into *PSO* for generating the initial population instead of generating it randomly in the standard *PSO*.

According to the second hybrid(*PSOTS)* algorithm, *TS* algorithm has been merged to the standard *PSO* to improve local research by avoiding the trap of the local optimality. This leads to improve the performance.

The proposed hybrid algorithms, *BFPSO, PSOTS,* have been implemented using the open source Cloudsim3.0.3 simulator with different number of independent tasks and different number of VMs.

The rest of this paper is organized as follows: Section 2 related work is discussed. In Section 3, the problem has been explained. In Section 4, problem statement is discussed. Sections 5 and 6 describe the proposed algorithms in detail, and its implementation and performance evaluation. Finally, section 7 presents the conclusions, and future research directions.

II. Related Work

In general, task scheduling is an important issue in any business, especially in Cloud computing, where it is considered as one of the main challenges facing the cloud computing because the service provider has to serve many users applications at different times and from different places. Therefore, schedule these tasks to be working on Cloud computing environment has to be more flexible and quick way. Thus, much research has been done in this field.

SolmazAbdi, Seyyed Ahmad Motamedi, and SaeedSharifia[8] have proposed a task schedule algorithm. The main principle of this algorithm is that the existed jobs and processors are sorted in ascending order. The processors are sorted based on their processing power. After sorting the jobs and processors, jobs are assigned using one to one mapping. After that, the Shortest Job to Fastest Processor (*SJFP*) algorithm is applied to generate initial population for the *PSO* algorithm. They used 4 VMs for evaluating performance of these algorithms, each VM has 4 GB of RAM and 30 GB of hard and 1 up to 4 of CPUs, in which each CPU has 2.3 GHz processing speed. In this task scheduling problem the criterion that is considered for evaluating performance is makespan. To test the performance of this algorithm, there are two different scenarios. In the first scenario, they changed number of tasks from 100 to 800. The second scenario is performed by changing number of iterations for constant number of tasks. Each experiment is repeated 10 times, and the final result is the average of all 10 iterations. The criterion that is considered for the performance of this algorithm is Makspan.

Gomathi B. Karthikeyan[9] has proposed a Hybrid Particle Swarm Optimization (*HPSO*) based scheduling heuristic to balance the load across the complete system while trying to minimize the makespan of a given task sets. In the *HPSO* algorithm, velocity of particles can be updated with vector differential operator from Differential Evolution (DE). Cognitive term in the velocity equation is replaced by the term containing the weighted difference (δ) between the position vectors of any two randomly chosen distinct particles from the whole population. The differential operator is used to provide additional exploration capability in search space. Particle is actually shifted to new location only if the new location gives better fitness value, then it is shifted to new location. The implementation results showed that *HPSO* algorithm is more efficient when compared with the standard *PSO* algorithm.

Shaobin Zhan, HongyingHuo Shenzhen[10] have improved the PSO algorithm to scheduling resources in the Cloud computing. This Improvement has been satisfied by introducing the simulated annealing heuristic with its fast random global searching ability for each iteration of the PSO algorithm to improve convergence rate, and guarantee the accuracy of the original PSO algorithm, which avoids sinking into local optima. They considered the estimation of both Genetic Algorithm and Simulated Annealing and builds up A calculation. As indicated by sort of the undertakings, the diverse weight of parameters can be given to discovering assets that fulfill the QOS of the errands and their desires. Calculation steps first execute ventures of GA after which toughening comes which helps to enhance nearby hunt capacity of GA. This calculation proficiently finishes the looking of assets and assignment process in distributed computing.

Through experiments, the results show that this algorithm can reduce the average running time, and raise the rate resources availability.

Ali Al-maamari, Fatma A. Omara[11] have merged the Cuckoo algorithm into the *PSO* algorithm, called *PSOCS*, to generate an optimal scheduling of tasks in the Cloud computing environment in order to complete the tasks in a minimum execution time, as well as, resources utilization. Cuckoo Search (*CS*) heuristic has been used to improve the load balance and avoid the trap of the local optimality. According to the proposed *PSOCS* algorithm, tasks have been assigned to a set of distributed VMs such that total execution time was minimized and system throughput was maximized.

III. Scheduling Problem Modelling

The goal of the task scheduling is to minimize the tasks' execution time, as well as, the execution cost, and optimize resource utilization. According to the work in this paper, the number of tasks is considered more than the number of resources (i.e., $n>>m$), and tasks cannot be assigned to different resources, that is, tasks are not allowed to migrate between resources.

To formulate the problem, consider the set of tasks is defined as $\boldsymbol{Ti} = \{\mathbf{1}, \mathbf{2}, \dots \boldsymbol{n}\}$where $\boldsymbol{n}$ is the number of independent tasks and $\boldsymbol{Rj} = \{\mathbf{1}, \mathbf{2}, \dots \boldsymbol{m}\}$is the set of computational resources. Suppose the execution of task ***i*** on VM ***j*** is defined as ***CTij***. The total execution time (i.e., Makspan) ***CTij*** is defined using the following equation[8],[12]:

$$Makspan = CTmax\ (i, j), i \in T,$$

$$i = 1,2, \dots n \ and\ j \in VM, J = 1,2, \dots m \qquad (1)$$

Where ***CTmax*** is the maximum time for completing task ***i*** on a virtual machine ***j.***

In addition, ***the total cost*** of executing all tasks on the available resources is calculated using equation (2) [13]:

$$Total\ Cost = \frac{Task\ length\ *\ \ Cost\ per\ seconds}{VM\ mips} + Processing\ Cost \qquad (2)$$

On the other hand, the utilization of resource represents the ratio between the total busy time of Virtual Machine and the total finish execution time of the parallel application. Therefore, Resources Utilization (***U***) for processing all tasks on VMs is represented by Equation (3)[5][11].

$$U = \frac{final\ VM\ available\ time}{\#VMs * schedulingtime} * 100 \qquad (3)$$

IV. PROBLEM STATEMENT

In the Cloud computing environment, a huge-scale computing task is typically split into several tasks, and finding a map between tasks and resources is achieved through visualization technologies. The major problem of task scheduling is to define the best mapping of ***n*** independent tasks into ***m*** heterogeneous resources(i.e., VMs) with the goal of minimizing the execution time (***Makespan***), and cost resources and maximizing resources utilization.

The goal of task scheduling is to create a mapping between tasks (***T***) and resources (***R***). i.e.;

$$\boldsymbol{f}: \boldsymbol{T} \rightarrow \boldsymbol{R}$$

In this paper, the *PSO, BFPSO, and PSOTS* algorithms have been applied to find ***f***. Note that, in this study, the following assumptions have been considered:

1- *tasks are independent and different sizes*
2- *The resources (i.e., VMs) are heterogeneous*
3- *The available resources are of exclusive usage and cannot be shared among different tasks.* It means that the resources (i.e., VMs) cannot consider other tasks until the completion of the current tasks is in progress.

V. THE PROPOSED ALGORITHM

The principles of the proposed *BFPSO* and *PSOTS* algorithms for task scheduling problem are based on *PSO*. First, the basics of the standard *PSO* algorithm will be introduced.

A The Standard PSO Algorithm

The basic idea of the *PSO* algorithm is that if one of the birds finds a good path to the prediction location, more followers would be attracted. This helps to improve the search for best path because all populations are involved. According to the PSO, every particle in the swarm behavior has two characters; (1) A position ***x*** which notates the suggested location. (2) A velocity ***v*** which defines the amount of moving. Each particle travels over the whole search space and remembers the best position found. The communication is made between particles such that each bird could determine the location and velocities based on the best solutions discovered by others. Each position and velocities are scored by a fitness function ***f*** to quantify the best solution. Specifically, at iteration ***k***, particles keep two values for each track; local best position ***(P_LB)*** and global best position ***(P_GB)***, both of which are calculated from ***f***. Therefore, the update function is defined using Equations(4) and (5)[5].

$$V(t+1) = wV(t) + c_1 * R1 * (pbest(t) - p(t)) + c_2 * R2 * (gbest(t) - p(t)) \qquad \textbf{(4)}$$

$$p(t+1) = p(t) + V(t+1) \qquad \textbf{(5)}$$

Wher***e V*** is the particle velocity, the variable ***W*** is called the inertia weight factor, ***p*** is the current solution, ***p best*** is a local solution, ***g best*** is a global solution, and ***R1***,***R2*** are the random numbers uniformly distributed on the interval [0,1].The variables ***C1, C2*** are the learning factors.

The pseudo code of the standard *PSO* algorithm is as follows [7].

PSO Algorithm

Set of particle dimension as equal to the size of ready tasks in **{ ti } ∈ T**

1. *Initialize particles position randomly from* ***PC= 1, ..., j*** *and velocity* ***vi*** *randomly.*
2. *For each particle, calculate its fitness value as in Equations (3), and (4)*
3. *If the fitness value is better than the prior* ***p_best****, set, the current fitness value as the new* ***p****_best.*
4. *After Steps 3 and 4 for all particles, select the best particle as* ***g_best****.*
5. *For all particles, calculate the velocity using equation (3) and update their positions using equation (4).*
6. *If the stopping criteria or maximum iteration is not satisfied, repeat starting from step 3.*

The flowchart of the standard *PSO* is presented in Figure 1.

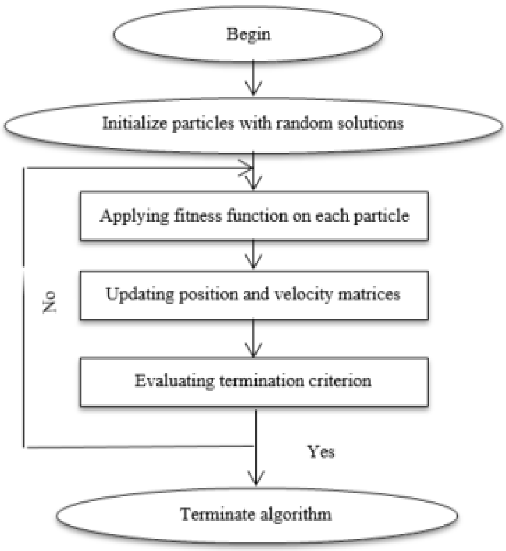

Fig. 1. Flowchart of Standard PSO Algorithm [13]

B Best-Fit -PSO Algorithm

In the standard *PSO* algorithm, initial particles are created randomly. Unfortunately, randomness could decrease the chance of the algorithm to converge to the best solution. In order to improve the behavior of the standard *PSO* algorithm, the Best-Fit (***BF***) algorithm has been merged into *PSO* algorithm, that is, instead of generating initial population randomly; it is created according to the *BF* algorithm. All other steps of the standard *PSO* algorithm are not changed. The flowchart of the modified *BFPSO* algorithm is shown in as Figure 2. For this purpose, the initial population is selected after sorting the tasks by priority, and allocating the ***m*** on to the suitable resources (i.e., VMs) with minimum running time according to *BF* algorithm[14].

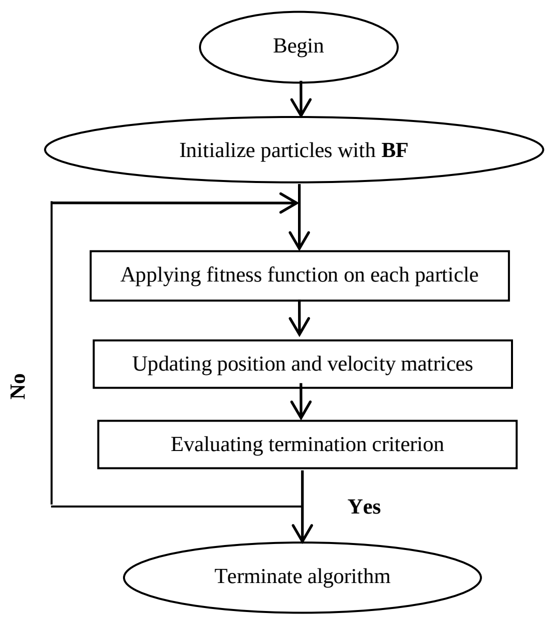

Fig. 2. Flowchart of BFPSO algorithm

C Tabu Search Based on PSO Algorithm

TS are a meta-heuristic procedure for solving problems. It is designed to guide other algorithms to escape the trap of local optimally. It has been applied to solve task scheduling and other optimization problems[15].

TS is a neighborhood search algorithm which employs intelligent search and flexible memory technique to avoid being trapped at the local optimum, and speed up the search process. The *TS* algorithm has been merged to the standard *PSO* algorithm to improve the local search where *PSO* algorithm searches and sends the results to the *TS* algorithm. The *TS* applies the neighborhood technology, adds the result to the Tabu list, compares the result and selects the best solutions. This situation is repeated until the best solution is obtained.

According to the example in Table [1], the neighborhood technology assigns with two minimum local execution time for any particle (i.e., VM3, VM4), and moves the tasks among VM1, VM3, and VM4, and uses Tabu list to restrict the search space to selects better solution [14],[16].

TABLE I. SHOW THE DISTRIBUTE THE TASK'S ON VM'S WITH TABU SELECT

Particle 0	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	Time
Instance 0	VM0		VM0	–	–	VM0	–	–	VM0	VM0	93.54
Instance 1	–	VM1	–	VM1	–	–	–	–	–	–	15.84
Instance 2	–	–	–	–	–	–	VM2	–	–	–	18.25
Instance 3	–	–	–	–	–	–	–	VM3	–	–	7.92
Instance 4	–	–	–	–	VM4	–	–	–	–	–	13.32

The flowchart of the modified PSO algorithm using TS algorithm is shown in Fig. 3.

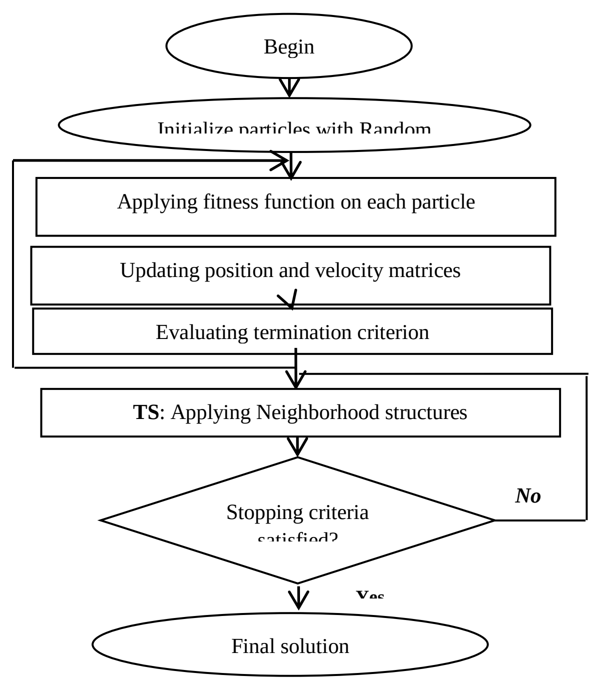

Fig. 3. Flowchart of PSOTS algorithm

VI. The Performance Evaluation

To evaluate the proposed hybrid algorithms, a comparative study has been conducted among the proposed *BFPSO*, *PSOTS* task scheduling algorithms and the standard *PSO* algorithm with considering the performance parameters of the standard *PSO* which are Makespan, cost of execution, as well as resource utilization.

A Experimental Settings

Cloudsim3.0.3 is an open source simulator which has been developed by Gridbus project team and the grid Laboratory of the University of Melbourne in Australia. The Cloudsim can run on Linux and Windows systems [6]. Cloudsim has been used to implement and compare the proposed *BFPSO, PSOTS* task scheduling algorithms with respect to the standard *PSO* algorithm. This simulation mainly validates the advantage of the Makespan, cost and the resource utilization among these scheduling algorithms in the Cloud computing environment.

B Performance Evaluation

To evaluate the performance of the three algorithms; the standard *PSO*, *BFPSO* and *PSOTS* algorithms, 15 Virtual machines are considered with 25, 50, 75,100, and 125 cloudlets (i.e., tasks).

It should be noted that the generation of the tasks using Cloudsim has been done randomly within a specific range of the tasks' length. This range has been defined to be 10000 to 75000 in our implementation.

The simulation results of the Makespan, resources utilization, and resources cost of the three algorithms, *PSO*, *BFPSO, and PSOTS*, using 15 Virtual machines and 25,50,75,100,125 tasks, are described in Tables[2], [3], [4],and Figs(4),(5),(6) and (7) respectively.

TABLE II. Makespan, Cost, and Resources Utilization of Standard PSO Task Scheduling Algorithm

No Of VM	*No of Task*	*Makespan*	*Utilization*	*Cost*
15	25	4.092052352	0.590684092	2447.8
	50	8.049770726	0.460671215	3459.6
	75	10.06010162	0.600100115	6348.2
	100	15.05739967	0.481335388	7656.6
	125	18.32775419	0.419473994	9158.6

TABLE III. Makespan, Cost, and Resources Utilization of BFPSO Task Scheduling Algorithm

No Of VM	*No of Task*	*Makespan*	*Utilization*	*Cost*
15	25	3.857488357	0.661309163	2170.8
	50	7.02620354	0.501536643	3430.6
	75	9.220183209	0.677329305	6110.2
	100	14.49099158	0.518613507	7463.4
	125	18.03631718	0.442760167	8972.4

TABLE IV. Makespan, Cost, and Resources Utilization of PSOTS Task Scheduling Algorithm

No Of VM	*No of Task*	*Makspan*	*Utilization*	*Cost*
15	25	3.609294627	0.70798141	2047.8
	50	6.928386256	0.57958908	3259.6
	75	9.194306359	0.70554259	5648.2
	100	14.91445344	0.55196318	7256.6
	125	17.60515986	0.48542686	8458.6

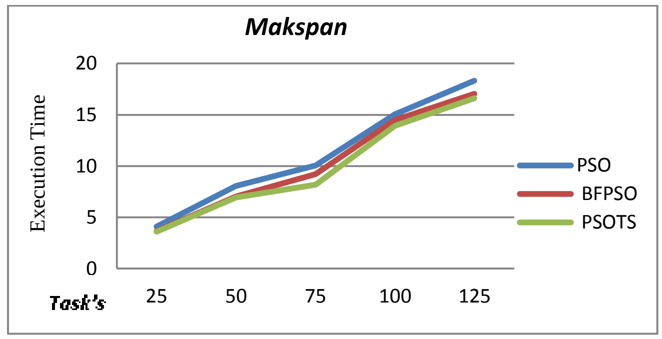

Fig. 4. The comparison of Makspan using three algorithms

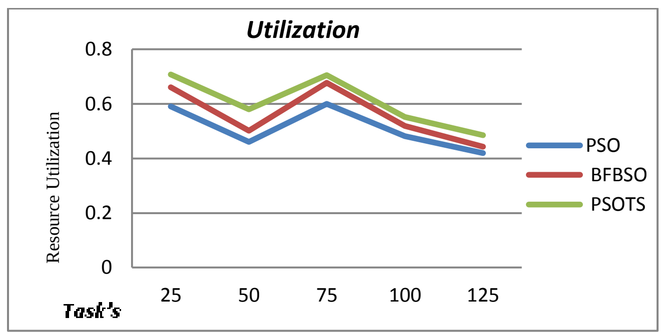

Fig. 5. The comparison of resource utilization using three algorithms

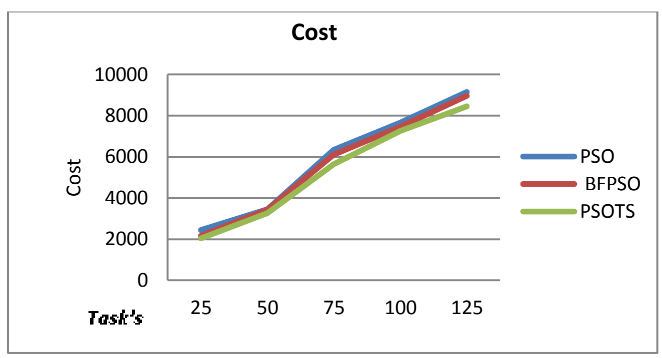

Fig. 6. The comparison of cost using three algorithms

According to the implementation results, it is found that the proposed *BFPSO* and *PSOTS* algorithms outperform the standard PSO with respect to Makespan by 5.32% and 7.85%

in average respectively. With respect to resource utilization, the two algorithms outperform the standard PSO by 8.54% and 14.68% on an average, respectively. With respect to cost, the proposed algorithms outperform the standard PSO by 3.18% and 16.34%, respectively in average (see Table [5]).

It notes that there is a variation when number of task 50 is increased to 75 tasks. This may happen because of the generated tasks with different length, and because VMs are heterogeneous.

TABLE V. AVERAGE IMPROVEMENT OF THE PROPOSED TWO ALGORITHMS RELATIVE THE STANDARD PSO

IMPROVE		
Parameter	BFPSO Vs PSO	PSOTS Vs PSO
Makspan	5.32%	7.85%
Resource Utilization	8.54%	14.68%
Cost	3.18%	16.34%

VII. CONCLUSION

In this paper, the problem of task scheduling in the Cloud computing environment is concerned. *BF*, *PSO* and *TS* algorithms are most famous algorithms for scheduling tasks in the distributed systems. In order to improve the performance of the standard *PSO* algorithm, the modified *PSO* algorithm is suggested, in which *BF* algorithm is merged into standard *PSO* algorithm for generating initial population in order to obtain a good initial selection. On the other hand, *TS* algorithm has been merged to standard *PSO* algorithm to avoid trapped and make an optimal local search to get a good solution by reducing the execution time (*Makespan*), cost of processing, and resources utilization.

The implementation results show that both proposed algorithms (i.e., *BFPSO* and *PSOTS*) outperform the standard *PSO* with respect to the Makespan, resource utilization and cost. Also, the proposed *PSOTS* algorithm has satisfied better results than that the proposed *BFPSO* algorithm. Unfortunately, this improvement has been satisfied at the expense of the time complexity of *PSOTS* algorithm.

In the future work, we plan to improve *PSO* by considering other greedy algorithms.

REFERENCES

[1] Shawish and M. Salama, “Inter-cooperative Collective Intelligence: Techniques and Applications,” a book chapter of Internet of Intelligent Things: Bringing Artificial Intelligence into Things and Communication Networks, pp. 39–68, 2014.

[2] An Oracle White Paper “Oracle Cloud Computing,” May, pp. 1–22, 2010. It is avaiable in https://www.mendeley.com/catalog/oracle-cloudcomputing/?utm_source=desktop&utm_medium=1.16.1&utm_campaign=open_catalog&userDocumentId=%7B6f362332-4682-41ce-a166-2c26a3c6decc%7D.

[3] R. Buyya, “Introduction to the IEEE Transactions on Cloud Computing,” IEEE Trans. Cloud Comput., vol. 1, no. 1, pp. 3–21, 2013.

[4] Ghorbannia Delavar and Y. Aryan, “HSGA: A hybrid heuristicalgorithm for workflow scheduling in cloud systems,” Cluster Comput,(The Journal of Networks, Software Tools and Applications) springer, vol. 17, no. MARCH 2014, pp. 129–137, 2014.

[5] G. Zhao, “Cost-Aware Scheduling Algorithm Based on PSO in Cloud Computing Environment,” International Journal of Grid and Distributed Computing, vol. 7, no. 1, pp. 33–42, 2014.

[6] S. Zhan and H. Huo, “Improved PSO-based Task Scheduling Algorithm in Cloud Computing,” Journal of Information and Computational Science (JICS)., pp. 3821–3829, 2012.

[7] S. Pandey, L. Wu, S. M. S. M. S. M. Guru, and R. Buyya, “A Particle Swarm Optimization-Based Heuristic for Scheduling Workflow Applications in Cloud Computing Environments,” 2010 24th IEEE Int. Conf. Adv. Inf. Netw. Appl., pp. 400–407, 2010.

[8] S. Abdi, S. A. Motamedi, and S. Sharifian, “Task Scheduling using Modified PSO Algorithm in Cloud Computing Environment,” International Conference on Machine Learning, Electrical and Mechanical Engineering (ICMLEME'2014) Jan. 8-9, 2014 Dubai (UAE)

[9] K. Gomathi, B Krishnasamy, “TASK SCHEDULING ALGORITHM BASED ON HYBRID PARTICLE SWARM OPTIMIZATION IN CLOUD COMPUTING ENVIRONMENT,” Journal of Theoretical and Applied Information Technology ,vol. 55, no. 1, 2013.

[10] Singh, Raja Manish Paul, Sanchita Kumar, Abhishek, “Task Scheduling in Cloud Computing : Review,” (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 5 (6) , 2014.

[11] Al-maamari and F. A. Omara, “Task Scheduling using Hybrid Algorithm in Cloud Computing Environments,” International Journal of Grid Distribution Computing Vol. 8, No.5, (2015), pp.245-256 .

[12] S. Saha, “A Survey on Resource Management in Cloud Computing,” (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 5 (3) , 2014.

[13] R. Sahal and F. A. Omara, “Effective Virtual Machine Configuration for Cloud Environment,” The 9th International Conference on INFOrmatics and Systems (INFOS2014) - 15-17 December Parallel and Distributed Computing Track Effective, pp. 15–20, 2014.

[14] Yi, Pan Ding, Hui Ramamurthy, “A Tabu search based heuristic for optimized joint resource allocation and task scheduling in Grid/Clouds,” 2013 IEEE International Conference on Advanced Networks and Telecommunications Systems (ANTS), Kattankulathur, 2013.

[15] Laguna, Manuel Barnes, J. Wesley Glover, Fred W., “Tabu search methods for a single machine scheduling problem, ” Journal of Intelligent Manufacturing,1991.

[16] S. S. Manimegalai, “Task Scheduling Using Two-Phase Variable Neighborhood Search Algorithm on Heterogeneous Computing and Grid Environments,” Arabian Journal for Science and Engineering, © King Fahd University of Petroleum andMinerals 2015.

An Approach for Integrating Data Mining with Saudi Universities Database Systems: Case Study

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Abstract*—This paper presents an approach for integrating data mining algorithms within Saudi university's database system, viz., Prince Sattam Bin Abdulaziz University (PSAU) as a case study. The approach based on a bottom-up methodology; it starts by providing a data mining application that represents a solution to one of the problems that face Saudi Universities' systems. After that, it integrates and implements the solution inside the university's database system. This process is then repeated to enhance the university system by providing data mining tools that help different parties -especially decision makers- to carry out certain decision. The paper presents a case study that includes analyzing and predicting the student withdrawal from courses at PSAU using association rule mining, neural networks and decision trees. Then it provides a conceptual and practical approach for integrating the resulted application within the university's database system. The experiment improves that this approach can be used as a framework for integrating data mining techniques within Saudi university's database systems. The paper concluded that mining universities' data can be applied as a computer system (intelligent university's system), Also, data mining algorithms can be adapted with any database system regardless that this system is new, exists or legacy. Moreover, data mining algorithms can be a solution for some educational problems, in addition to providing information for decision makers and users.

Keywords—Data Mining; Database; Predict; Integration; Association rule mining; Neural networks; Decision tree; Educational Data Mining (EDM); University system

I. Introduction

Nowadays, higher educational institutes face many challenges in fulfilling the needs and requirements of stake holders such as students and their parents, the public sector, the labor market and the community, besides the challenges of what is called the "revolution of academic accreditation". In additional to these challenges, the universities should keep pace with traditional issues such as predicting student enrollment and graduation rates, and the challenges of managing educational process to motivate higher educational institutes to search for better solutions. One way to effectively address these challenges is to use data mining technologies. Data mining has become one of the most valuable tools for extracting and manipulating data. It also used for establishing patterns in order to produce useful information for decision-making. Recently, data mining is used in educational field to bring a new field of study called Educational Data Mining (EDM). EDM focuses on collecting, archiving, and analyzing of data related to student learning and assessment in educational institutes. Through EDM, a university could, for example, predict academic outcomes, predict which students will or will not withdraw courses, predict which students will or will not graduate…etc. Also, using EDM we can get answers for many questions such as: what do institutions know about their students? Which courses have most withdrawal rate? What types of courses will attract more students? ...etc.

Recently, the usage of data mining in higher education has received more attention, although this doesn't apply to Saudi universities. (To the best of our knowledge, there is no use of data mining technologies in any Saudi university's educational system).

This paper tries to introduce data mining application to educational systems in Saudi universities; it provides an approach for using data mining algorithms in solving typical educational university problems and then propose an approach to integrate the proposed solution with Saudi university's database system.

There is a large number of research, experiments and projects in the area of EDM. For example:[1],[2], [3] and[4] work on the area of analyzing and predicting the course outcomes such as; classifying the student's success in one course, predict passing/failing rates in a course, predict withdrawal rates in a course and predict student's score in a course, while [5], [6], [7] and [8] work on the area of analyzing the performance of the academic and educational environment.

Also,[9],[10], [11] and [12] work on the area of analyzing, classifying and predicting academic success for students in a certain university level. In addition to predicting student performance, her/his graduation time, drop-out and general performance are analyzed, while in [13] the authors work in the area of examination and assessment , tackle predicting student's success in the next exam given her/his answers of previous exam. Also, they address predicting student's score in the next exam, and correctness of the student's answer.

In [14] and [15] the authors work on the area of metacognitive skills, habits, and motivation such as: predicting the student's motivation or engagement level, his cognitive style, his experience in using the learning system, and recommended intervention strategy.

This paper contributes to the field of EDM by presenting a methodology to carry out the following:

1) Adapting data mining algorithms with database systems.

2) Providing an approach that might be used as a framework for integrating data mining techniques with Saudi universities' database systems.

3) Providing solutions (prediction and analysis) to one of the problems that is facing most Saudi universities (courses withdrawal).

4) Developing an EDM application.

The rest of this paper is organized as follows: section 2 presents the proposed approach, section 3 presents the experiments, and in section 4 results and conclusions are deduced.

II. The Proposed Approach

This section describes the process of integrating data mining techniques with Saudi university's database system through a practical experiment. This is done based on a methodology that works in two phases (figure 1):

Phase one: (solving the problem)

In this phase, the problem (task) is selected and then developing a data mining application as a solution for the selected problem. This process includes the following steps:

1) Specify the problem.

2) Analyze the problem.

3) Specify and collect the dataset that is required for mining this task.

4) Prepare and preprocess the dataset (D1)

5) Develop the application.

Phase two: (integrate the solution)

This phase for integrating the application that is developed in phase one with the university's database system. The process of integration is achieved by the following steps:

1) Select the needed data for university database.

2) Add the selected data to application dataset (D1); producing in the new dataset (D2).

3) Update the data mining application to deal with the new dataset, resulting in the final data mining application.

4) Embed the application inside the university system (this can be done by adding the application's user interface and the reports inside the university user interface system – unifying the system).

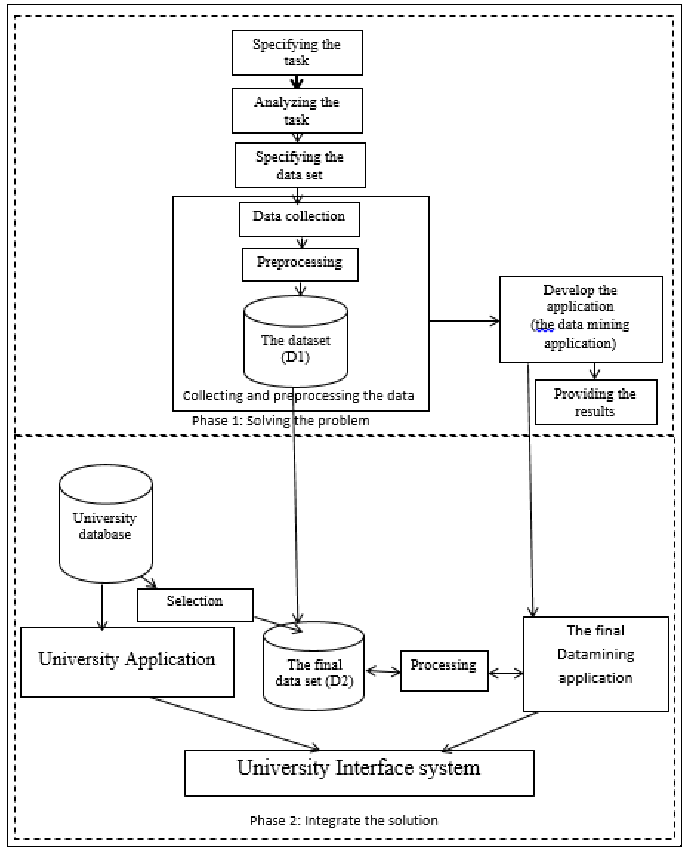

Fig. 1. The approach of integrating data mining techniques with the university's database system

This methodology can be used as an approach for embedding any type of data mining algorithm with Saudi university's database system. The idea of this approach is to select the required tasks and then apply the aforementioned steps for each task, continually. This concept, allow this approach -besides the integration of data mining techniques with university's systems- to provide two benefits:

- Well-defined life cycle for applying and integrating data mining techniques in university's database systems for certain tasks (figure 2).
- Flexibility in using and implementing any data mining technique in university's systems. Hence, it isolates the implementation of data mining technique (the data mining application) from the running university system. This is because that the approach provides the integration through the user interface without the need to implement the algorithms within the university application. In addition, the dataset that is used by the data mining technique is also isolated from the university database.

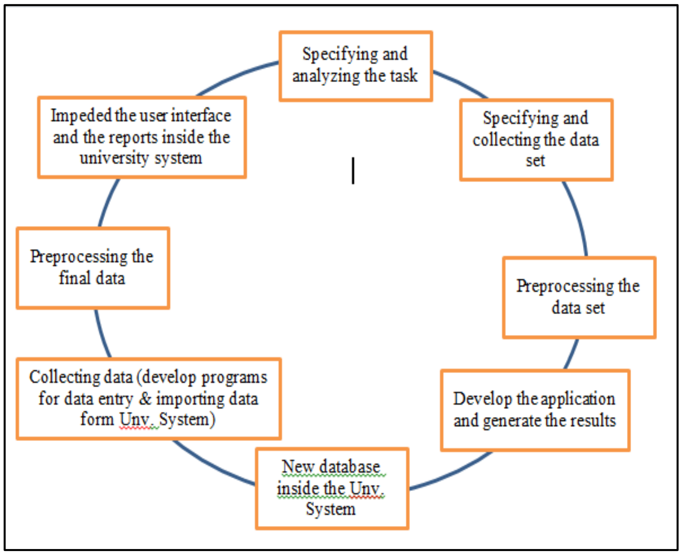

Fig. 2. The life cycle for integration data mining techniques with university's database system

III. The Experiment

This section presents the experiment of the suggested approach. The experiment will be conducted at Prince Sattam Bin Abdulaziz University as case study of Saudi public universities.

A. *Developing the datamining application (phase 1):*

1) Specifying and analyzing the task:

Most of Saudi Universities allow students to withdraw from courses within 12 weeks after registration, bearing in mind that there are no fees for course registration or course withdrawal. Therefore, in every semester there are a considerable number of students who withdraw from one or more courses. Accordingly, withdrawal from courses constitute an academic burden and it is negatively affecting the educational process by: delaying student's graduation, affecting the performance of the programs, and sometimes affecting the following-up of the academic program specially when offering different optional courses.

The experiment will examine, analyze, and predict the student course withdrawal by applying association rule mining, neural networks and decision trees algorithms. The experiment integrates these algorithms in one application and then directly provides results that can support decision making and also provides a user interface that advises and helps students during course registration to avoid withdrawal.

In this experiment the implementation will be done inside the College of Computer Engineering and Sciences at Prince Sattam Bin Abdulaziz University, as specific case study. The final application can then be embedded into the university system, and can then be applied for all university colleges. The developing of the final application follows the algorithm that is shown in figure 1.

College of Computer Engineering and Sciences offers four programs, each program offers many courses, every student must enroll in one program but according to the program's curriculum, students have to take some courses that are offered by other departments.

2) The dataset:

The most important data for analyzing and predicting student withdrawal from courses is reasons of the withdrawal (table 1). Unfortunately, such kind of data is not available in the university database. Accordingly, we surveyed 135 students to collect possible reasons for withdrawal from courses, 135 questionnaires have been distributed and filled by the selected students (students who withdrew courses in previous semesters). The responses of students to the closed-ended questions (mainly related to the reasons for withdrawal from courses) are used to build a database table to serve as a dataset for our experiment. Table 2 shows an example of the final records that preprocessed from the questionnaires.

TABLE I. Examples of Reasons of Withdrawal from Course at PSAU

1.	The instructor (teacher): student disagree with or unlike the instructor
2.	Changing of the instructor (teacher): some time, for some reasons, the department changing course's instructor after registration
3.	Absent : student did not attends all the classes, so he may afraid to be denied or he found difficult in understanding or in following-up the course.
4.	Subject difficulty: student found that some or most of course subjects are difficult.
5.	Bad results (low marks): student found that his performance in the course work is not good (he obtain low marks in the course work), so he afraid to fail or he did not agree with his results.
6.	Option course: Because student has many choices, he may withdrawal from the option course to select another one next semester.
7.	Course timetable: Student may found that the course timetable is not suitable (he struggling in attending the classes)
the reasons has been specified according to results of direct interview with samples of students and academic advisors	

TABLE II. Example of the Questionnaire Data After Preprocessing (The Reason of Course Withdrawal and Its Relation with the Department and the Subject)

#	Subject	Sub. Tea.	Tea. Change	Absence	Sub. Diff.	Sub. Time	Low Marks
1	Computer Network Systems	Yes	No	No	Yes	No	No
2	Computer Network Systems	Yes	No	No	Yes	No	No
3	Mobile Application	Yes	No	Yes	No	Yes	Yes
5	Discrete Mathematics	No	No	Yes	No	No	No
6	Logic Lab	Yes	No	No	No	No	No
8	Computer Network Systems	Yes	No	No	Yes	No	No
9	Web Applications Programming	No	No	No	Yes	No	No
10	Operating system	Yes	No	Yes	No	No	No

3) The application:

The application is designed to analyze and predict student's withdrawal through single user interface. In this application three data mining algorithms are used: Neural Networks (figure 3), Association Rule Mining (figure 4) and Decision Trees (figure 5). These algorithms is used to ensure that the application has the ability of applying different algorithms in predicting student's withdrawal. SQL Server data mining because it is compatible with the University's database system and it has the ability to build multiple models on a single mining structure.

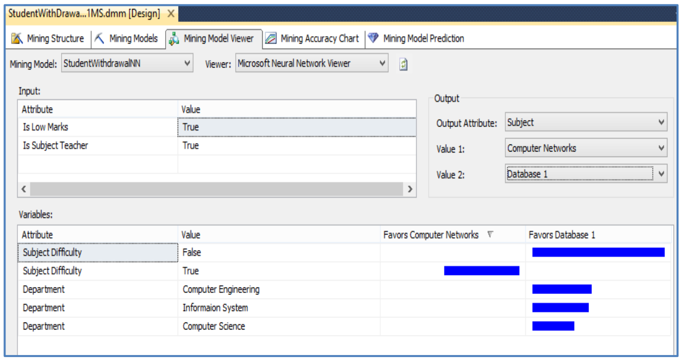

Fig. 3. The implementation of the neural networks data mining algorithm (Student withdrawal data mining application)

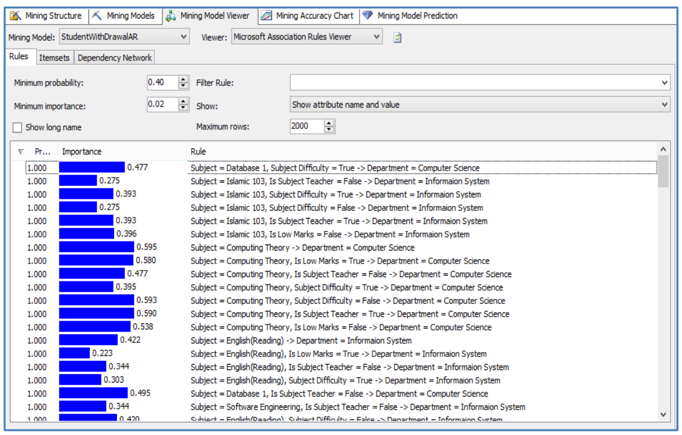

Fig. 4. The implementation of the association rule mining algorithm (Student withdrawal data mining application)

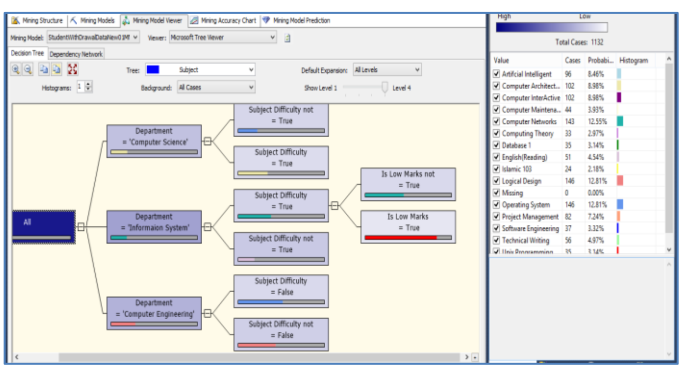

Fig. 5. The implementation of the decision trees algorithm (Student withdrawal data mining application)

These algorithms are integrated into one user interface in which the user can then choose the algorithm, subject, confidence, … etc. Then, results appear providing the prediction for the student's withdrawal from courses according to the selected mining algorithm (figure 6).

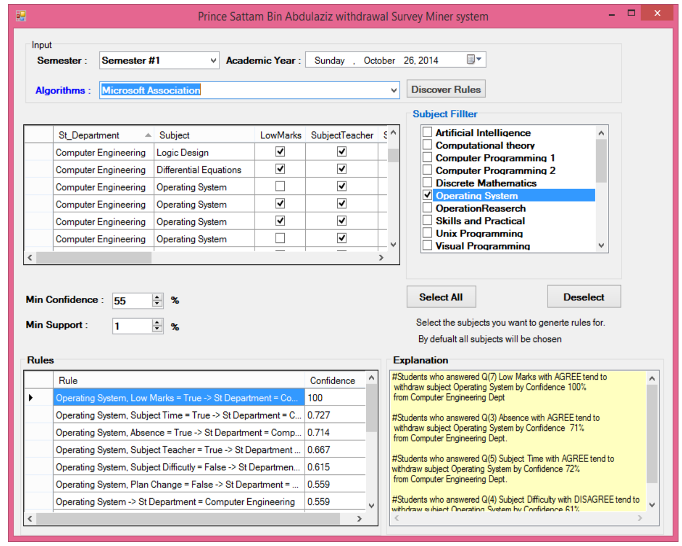

Fig. 6. Student withdrawal data mining application (main interface)

B. Integrating the solution (phase 2)

1) The final dataset

The final database is designed to handle data coming from two datasets:

a) The first dataset is about reasons of withdrawal. This data has been created and developed in the previous phases (see figure 1 – D1).

b) The second dataset is for the information about students, courses, and instructors. This kind of data is selected directly from the university database.

These two datasets are then joined in one database to present the final dataset for the final data mining application (see figure 1).

2) The final datamining application:

In this stage the final data mining application is developed. The application is designed and developed to be an automatic application (computer system) that can run automatically inside the university system without any manual processing. To provide this concept, the final datamining application (the mining system) is designed to perform the mining through three stages:

- At the first stage, the application constructs the classifier (figure 7).
- At the second stage, the application uses the classifier for classification (figure 8).
- Al last, all the processes are provided through an online application (figure 9).

The first step: constructing the classifier:

In this step, the classification algorithm constructs the classifier from the training set made up of database records and their related class name coming from the final dataset (D2). Figure 7 explains the construction of the classifier.

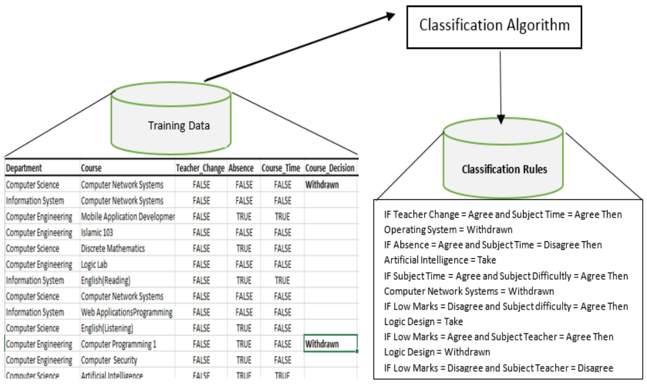

Fig. 7. Classification algorithms

The second step: The classification:

In this step, the classifier is used for classification. Here the test data is used to estimate the accuracy of classification rules. Figure 8 explains the use of the classifier for classification.

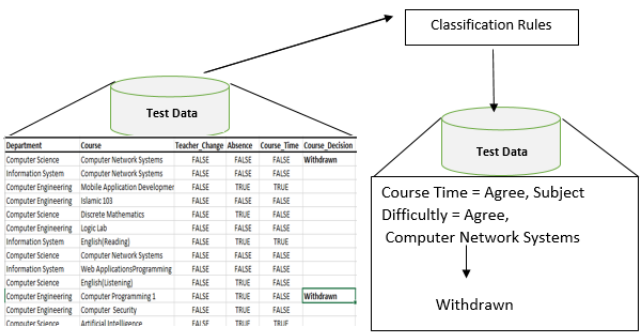

Fig. 8. Classification Rules

The last step: The online data mining application:

At the final stage, all these processes are provided online through a single user interface form (figure 9). The user can then interact with the mining system through the online system's interface by selecting the corresponding items (figure 9).

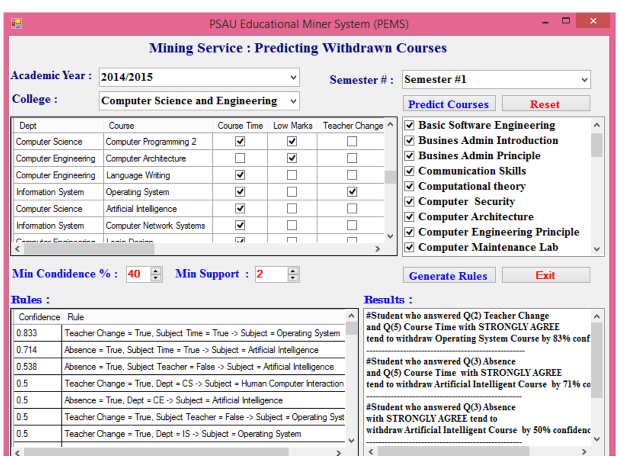

Fig. 9. PSAU Educational Miner System interface

The system provides predicting results based on the mining algorithm that is selected by the user, for example figures 9 and 10 show the results of predicting the withdrawal of three courses (Artificial Intelligence, Operating Systems and Human Computer Interaction). These results are based on three classification models built automatically when the user select the required items and press the appropriate buttons. The system gives a confidence percentage for this prediction by comparing predicted percentage with set minimum confidence.

#Student who answered Q(3) Absence
and Q(5) Course Time with STRONGLY AGREE
tend to withdraw Artificial Intelligent Course
by 71% confidence.

#Student who answered Q(3) Absence
with STRONGLY AGREE tend to
withdraw Artificial Intelligent Course
by 50% confidence from CE Dept.

#Student who answered Q(2) Teacher Change
with STRONGLY AGREE tend to withdraw
Human Computer Interaction subject
by 50% confidence from CS Dept.

Fig. 10. Samples of some predicted results

The final mining system:

The final mining system that is provided by this experiment is now tested and ready to run within the university system. The student and the decision maker can make use of this system. For example, student can choose the right course to avoid any future needs for withdrawal, the decision maker can get a lot of information that can help in developing the right action plan regarding the processing of the teaching and the registration processes.

At any semester, student can withdraw courses, which means new withdrawal data is arising continually, this kind of data is most close to reality; hence, it is affected by the current situation of the registration process. Accordingly, we make use of this data by providing new interface form to collect these kind of data instead of using the questionnaire, to keep the automaticity of the system, provide the continuation of the system, and to let the system be more intelligent by adding the new data to the old dataset (learning knowledge base concept) (figure 11). When the student decides to withdraw a course, then he will be asked through this form to enter the reasons of withdrawal, his answers then are added to our database (dataset D2). Accordingly, the users deal with the system as follow:

a) At the registration period, the student can check the probability of the withdrawal of the courses he is going to register, the reasons that he may face during the semester, so he will make his right decision. For example, if he afraid from the time, or the instructor of the course he then asks the system what is the possibility of withdrawal of this course because of the time or the instructor.

b) The administrators can make the right action plan. For example they can solve or avoid the reasons that may affect the withdrawal rates when offering courses at the beginning of each semester.

c) When the student decides to withdraw from course(s) he/she will be asked to enter the reasons of withdrawal (figure 11) this data is then added automatically to the system dataset. (And so on, the cycle will continue starting from 1 or 2 above, according to who will use the system – student or the decision maker).

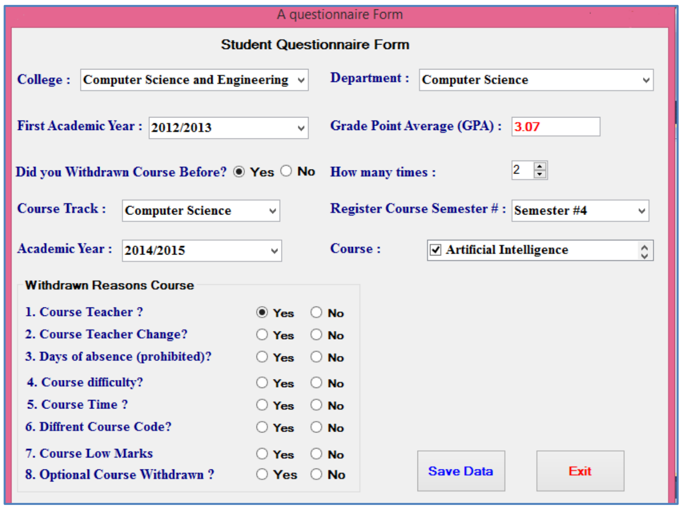

Fig. 11. Reasons of withdrawal (data entry form)

IV. Results and Conclutions

The paper presents an approach for embedding data mining algorithms with Saudi university's database systems. The approach is based on a concept that embeds data mining algorithms with the running university system by developing a separate application and separate dataset, and then integrates all the processes with the university system through unifying the application user interface with the university system user interface. This concept provides more flexibility in using and implementing any data mining technique in university systems.

The approach is tested at Prince Sattam University (one of Saudi public universities). The experiment shows that a data mining algorithm can be embedded into the Saudi university's system and would provide intelligent results that might help students, parents and decision makers. In addition, the experiment shows that data mining algorithms can be implemented as a computer system running automatically in a continuous manner without any intervention or manual preprocessing.

The experiment concludes that the approach can be used as a framework for integrating data mining techniques with Saudi universities' database systems, besides providing solutions (prediction and analysis) to one of the problems that is facing most of Saudi universities: courses withdrawal.

This paper concludes that, mining universities data can be applied as a computer system (intelligent university system), data mining algorithms can be adapted with any database system whatever this system is new, exists or legacy, and data mining algorithms might provide solutions for some educational problems, in addition to providing information for decision makers and users.

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References

[1] Calders, Toon, and Mykola Pechenizkiy. "Introduction to the special section on educational data mining." ACM SIGKDD Explorations Newsletter 13.2 (2012): 3-6.

[2] Chacon, Fabio, Donald Spicer, and A. Valbuena. "Analytics in support of student retention and success." Research Bulletin 3 (2012): 1-9

[3] Hämäläinen, Wilhelmiina, and Mikko Vinni. "Classifiers for educational data mining." Handbook of Educational Data Mining, Chapman & Hall/CRC Data Mining and Knowledge Discovery Series (2010): 57-71.

[4] Yamamoto, Yukiko, et al. "Increasing the Sensitivity of a Personalized Educational Data Mining Method for Curriculum Composition." Emerging Issues in Smart Learning. Springer Berlin Heidelberg, 2015. 201-208.

[5] Bienkowsk Marie i, Feng Mingyu and Means Barbara. 2012." Enhancing Teaching and Learning Through Educational Data Mining and Learning Analytics: An Issue Brief". Technical report. U.S. Department of Education. Office of Educational Technology. October 2012

[6] Delavari Naeimeh, Phon-Amnuaisuk Somnuk and Beikzadeh Mohammad Reza 2008. " Data Mining Application in Higher Learning Institutions" Informatics in Education, 2008, Vol. 7, No. 1, 31–54 31

[7] Titus deLaFayette Winters. 2006. "Educational Data Mining: Collection and Analysis of Score Matrices for Outcomes-Based Assessment". PhD. Thesis in Computer Science. UNIVERSITY OF CALIFORNIA RIVERSIDE

[8] Zare Ali Akbar, Gerayeli Mohamad, Zare Davoud, and Tadayon Hamed. 2013."Teachers Salary Data Analysis using Data Mining Techniques" European Journal of Economics, Finance and Administrative Sciences

[9] Arockiam, L., S. Charles, and M. Amala Jayanthi. "An Impact of Emotional Happiness and Personality in Students' Learning Environment." Data Mining and Knowledge Engineering 7.2 (2015): 69-74.

[10] Baradwaj, Brijesh Kumar, and Saurabh Pal. "Mining educational data to analyze students' performance." arXiv preprint arXiv:1201.3417 (2012).

[11] Chalaris, Manolis, et al. "Examining students' graduation issues using data mining techniques-The case of TEI of Athens." Proceedings of the 4th International Conference on Integrated Information. Vol. 1644. AIP Publishing, 2015.

[12] Patidar, Preeti, Jitendra Dangra, and M. K. Rawar. "Decision Tree C4. 5 algorithm and its enhanced approach for Educational Data Mining." (2015).

[13] Foltz, Peter W., and Mark Rosenstein. "Analysis of a Large-Scale Formative Writing Assessment System with Automated Feedback." Proceedings of the Second (2015) ACM Conference on Learning@ Scale. ACM, 2015.

[14] Baker, Ryan Shaun, and Paul Salvador Inventado. "Educational data mining and learning analytics." Learning Analytics. Springer New York, 2014. 61-75.

[15] Ocumpaugh, Jaclyn, et al. "Population validity for Educational Data Mining models: A case study in affect detection." British Journal of Educational Technology 45.3 (2014): 487-501.

A Memetic Algorithm for the Capacitated Location-Routing Problem

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***Abstract*—In this paper, a hybrid genetic algorithm is proposed to solve a Capacitated Location-Routing Problem. The objective is to minimize the total cost of the distribution in a network composed of depots and customers, both depots and vehicles have limited capacities, each depot has a homogenous vehicle fleet and customers' demands are known and must be satisfied. Solving this problem involves making strategic decisions such as the location of depots, as well as tactical and operational decisions which include assigning customers to the opened depots and organization of the vehicle routing. To evaluate the performance of the proposed algorithm, its results are compared to those obtained by a greedy randomized adaptive search procedure, computational results shows that the algorithm gave good quality solutions.**

Keywords—hybrid genetic algorithm; capacitated location-routing problem; location; assigning; vehicle routing

I. Introduction

Managing distribution is one of the most challenging problems for companies that aim to minimize the costs of their activities and meet the customers' needs in an environment where the competitiveness continues to increase.

Location problems and routing problems have long been treated separately, combining these two problems is the location and routing problem (LRP) whose objective is to optimize the costs of the distribution in a logistic network in taking strategic decisions that relate to the location of facilities, and allocation and organization of vehicle routing which are solved at the tactical and operational levels.

Salhi and Rand highlight the importance of tackling both problems simultaneously and the effect of ignoring routes when locating depots [1]. There are different formulations of the LRP, some consider depots and vehicles with limited capacities [2], while others, such as List and Mirchandani [3], offer formulations without capacity constraints. Wu et al. [4] have considered constraints on the vehicles and formulated a model for LRP with limited heterogeneous fleet, and Liu and Lee included inventory costs in LRP [5]. The reader is referred to the survey by Nagy and Salhi [6] for more LRP variants.

Exact methods have been proposed to solve the Capacitated Location-Routing Problem (CLRP), Laporte et al. [7] solved the problem through a branching method based on the relaxation of subtour elimination and the chain baring constraints, Baldacci et al. [8] and Contardo et al. [9] found good quality solutions to the LRP using exact methods ; Baldacci Proposed a branch and price algorithm and Contardo developed an algorithm based on cut-and-column generation for the CLRP. Prins et al. [10] solved the CLRP with a Greedy Randomised Adaptive Search Procedure (GRASP) followed by a path relinking algorithm and Duhamel et al. [11] proposed a GRASP hybridized with Evolutionary local search (GRASP X ELS) while Ting et al. [12] proposed a multiple ant colony optimization algorithm. Prodhon [13] presented a survey on the CLRP methods of resolution and other variants of the LRP. Our point of focus in this paper is on the evolutionary algorithms that are presented in the sequel.

Genetic algorithms have been proposed for the first time by J. Holland (1962), and then developed by D. Goldberg (1989), they are inspired by the natural evolution in genetics, where a population of individuals represents a set of solutions, an individual is represented by a chromosome and each chromosome contains genes.

Genetic algorithms have been successfully applied to the resolution of combinatorial optimization problems, several algorithms have been developed; Potvin [14] have presented a genetic algorithm for the Traveling Salesman Problem (TSP), Zhao [15] proposed a hybrid genetic algorithm to solve a TSP with pickup and delivery, while Prins [16] have presented an efficient genetic algorithm to solve the vehicle routing problem (VRP), Vidal et al. [17] have also used genetic algorithm to solve a multi-depot and periodic vehicle routing problem. For an overview of genetic algorithms, Reeves' book [18] is a good reference.

The first step of a genetic algorithm is to initialize the population and represent it in the form of chromosomes. The first generation is often randomly generated. The second step is to assess the individuals of a population in order to measure the goodness of each solution and select them according to their fitness in order to enable the best chromosomes to survive, then comes the stage of the crossover which involves crossing two chromosomes parents in order to obtain one or two new children called offspring. An offspring is better than the parents if it takes the better part of each. After the crossover, a mutation can be applied to the obtained children in order to prevent a premature convergence of the algorithm. In the incremental mode, only two parents breed and their children are integrated in the current population, while in the generational mode, each iteration reproduces all the children who will be the next generation.

Genetic algorithms provide results of good qualities but hybridized with a local search, the results are better, the two methods complement each other; the first explores the different regions of the search space while the other exploits it intensively [19]. Local research is a powerful means to obtain quality solutions for optimization problems, it allows improving a solution by exploring its neighborhood, the latter is obtained by applying transformations to the solution, the best solution of this neighborhood is called a local minimum.

Genetic Algorithms hybridised to a local search are called Memetic algorithms. they have been introduced by Moscato in 1989 [19], they have led to excellent results for different problems, Krasnogor and Smith [20] have reviewed some applications of memetic algorithms to well known combinatorial optimization problems and Neri and Cotta have presented a literature review of these algorithms [21]. Various memetic algorithms have been developed for routing problems; Freizleben and Mertz [22] used it to solve the TSP, Cattaruzza et al. [23] for the multi-trip vehicle routing, Mendoza et al. [24] for the multi-compartment vehicle routing problem with stochastic demands, Prins [25] and Lima et al. [26] have proposed memetic algorithms to solve heterogenous fleet vehicle routing problem. The most recent method has been proposed by Sörensen and Sevaux [27], it is a memetic algorithm with population management (MA/PM) that defines a measure of distance in order to diversify the chromosomes parents of the algorithm.

This paper aims to solve a capacitated location routing problem while minimizing the total cost which includes the depots opening cost, the vehicles cost of use and the routing cost using a memetic algorithm. The paper is organized as follows: Section II describes the problem, the algorithm and its components are presented in Section III, Section IV provides the parameters used and computational experiments and some concluding remarks are presented in Section V.

II. PROBLEM DESCRIPTION

In this paper a capacitated location routing problem is treated. Let $G=(V,E,C)$ be a weighted complete graph where $V = Dep \bigcup Nsc$, Dep is the set of potential depots to open and Nsc is the set of customers to serve, $E=\left\{(i;j): i \in V, j \in V, i \neq j\right\}$ is the set of arcs linking the different nodes in the graph and $C=\left\{c_{ij} / i \in V, j \in V\right\}$ where c_{ij} is the cost of the trip via the arc (i,j) . Each depot i has a limited capacity Cap_i , a fixed cost of opening O_i and a homogeneous fleet F_i of vehicles v_{im} of a capacity cpv_{im} and a cost of use vc_{im} . There is no limit on the number of vehicles. Each customer j has a demand d_j which must be satisfied. A vehicle can serve multiple customers during his tour but a customer is served by only one vehicle. Each vehicle returns to its depot of departure after the last visited customer. We assume that the overall capacity of the depots satisfies the demand of all customers and that the request of a customer does not exceed the capacity of a vehicle. The objective is to minimize the total cost which is the sum of the depots opening costs and the routing costs while responding to all the customers' requests.

III. A MEMETICALGORITHM FOR THE CLRP

In order to solve this problem, a memetic algorithm is proposed, this section includes the details of its different components.

A. Initial population

The initial population is obtained using a constructive algorithm based on the principle of the Nearest Neighbor Search (NNS), depots to be opened are randomly selected, which allows the exploration of the solutions space. In the sequel, Ct represents the solution cost, the variables x_i and y_{ijm} take respectively the value 1 if the depot i is open and if the customer j is served by the depot i via the vehicle v_{im} , 0 otherwise.

Fig. 1. presents the steps of the proposed algorithm, it starts by opening a depot selected in a random way, as long as its capacity allows, the closest customer to the last visited node which is not yet served is assigned to it, once the depot capacity no longer allows to provide customers, the approach is reiterated and another depot is opened until all customers are affected.

Note: During the initialization of the population, it is necessary to check that there are no clones, in case two chromosomes have equal costs, one of them is deleted and replaced by another one selected randomly.

B. Solution encoding

Solutions encoding is an important step that can influence the performance of genetic algorithms, in the proposed algorithm, the encoding method proposed by Prins [28] is adopted, each

Procedure: GenInitialSol
Input : Problem' data values
Output : Initial solution

$Ct \leftarrow 0$
repeat
Select randomly an available depot p
$x_p \leftarrow 1$
$Dep \leftarrow Dep - \{p\}$
$m \leftarrow 1$
$Ct \leftarrow Ct + O_p + vc_{pm}$
$j \leftarrow p$
repeat
$l \leftarrow \arg\min_{k \in Nsc} \left\{c_{jk} / cap_p > d_k and d_k < cpv_{mp}\right\}$

$y_{plm} \leftarrow 1$
$Cap_p \leftarrow Cap_p - d_l$
$Nsc \leftarrow Nsc - \{l\}$
$cpv_{pm} \leftarrow cpv_{pm} - d_l$
$Ct \leftarrow Ct + c_{pl}$
$j \leftarrow l$
if ($\forall k \in Nsc, d_k > cpv_{mp}$) then
$m \leftarrow m+1$
$Ct \leftarrow Ct + c_{jp} + vc_{pm}$
end if
until ($Cap_p < d_l$)
until ($Nsc = \emptyset$)
return the initial solution

Fig. 1. The procedure to generate an initial solution

solution is represented as a chromosome, the latter indicates the status of the depots as well as the allocation of customers to opened depots. Each chromosome consists of two sequences, the first relates to the depots and the other to the customers, there is no trip delimiter. If a gene of the depots sequence is zero, this means that the depot is closed, otherwise it contains the index of the first customer assigned to it. The customers sequence is a concatenation of trips.

For each chromosome S, vectors ds and cs represent respectively the depots and the customers sequences. Fig. 2. represents an example of a chromosome, the depot 2 is closed because $ds(2) = 0$, the depot 1 is open, the set of customers affected to it is $C_1 \leftarrow \{1,2,3,4\}$, this sequence begins with the first customer assigned to the depot and ends by the one just before the first customer assigned to another opened depot, depot 3 is also open and the set of customers affected to it is $C_3 \leftarrow \{5,6,7,8,9,10\}$.

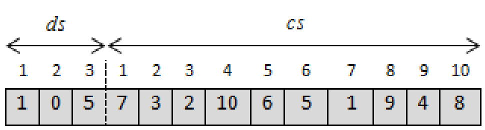

Fig. 2. Example of a chromosome

C. Selection and crossover

The first parent is selected using the binary tournament method on half of the best individuals of the population, the second also is chosen with this method but this time on the whole population except the first chosen parent. A single child is kept randomly, it gives better results than keeping the best one or both.

Crossover for the depots sequence acts as on a sequence of binary (one crossover point), a cut-off point is randomly chosen between 1 and $l_d - 1$ where l_d is the length of the depot sequence. The depot part of the child consists of the left part before the cut point of the first parent and the right part after the cut point of the second parent. The classical order crossover (OX) is used to obtain the customers sequence, two cut points p and q are chosen randomly, such as $1 \prec p \prec q \prec l_c - 1$, where l_c is length of the customers sequence. The part between the two cut points of the first parent is copied in the same order and in the same position in the child chromosome, then the latter is supplemented by scanning the genes of the second parent from the position $q+1$ up to l_c, then from the position 1 up to q and copying each element not yet in the child.

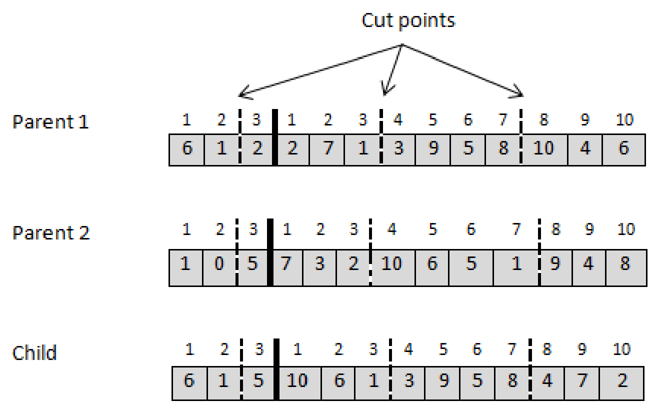

Fig. 3. Example of chromosomes crossover

D. Chromosome repair

After the crossover, it is necessary to check that the chromosome obtained is valid, we begin by verifying that all customers have been assigned, it is sufficient to check the existence of 1 in the depots sequence, it is also necessary to verify that the depots capacities have been respected, if this is not the case, customers should be removed one by one from such a the depot and assigned to the nearest one whose capacity allows, until all depots capacities are respected. If none of the opened depots allows it, a closed depot is opened. Fig. 4. describes the repair procedure steps. Variables C_i and Sd_i represent respectively the set of customers assigned to a depot i and the sum of customers assigned to this depot demands. The function $Close(j,E)$ returns the index of the nearest node to j in a set of nodes E .

Procedure: ChromRepair
Input : A chromosome S
Output : Repaired chromosome

Find i / $ds(i) = 1$, if it fails, find the first closed depots i' and $ds(i') \leftarrow 1$
for each $i \in Dep$ **do**
if ($ds(i) \neq 0$ **) then**
for each $j \in C_i$ **do**
if ($Sd_i > Cap_i$ **) then**
repeat
$j' \leftarrow$ last customer affected to i

$i' \leftarrow Close(i, Dep) / x_i = 1$ and $Cap_{i'} > Sd_{i'} + d_{j'}$

$C_i \leftarrow C_i + \{j'\}$

$C_{i'} \leftarrow C_{i'} + \{j'\}$

if ($i' = \varnothing$ **) then**

Find $i'' / \ ds(i'') = 0$

$ds(i'') \leftarrow 1$

$C_i \leftarrow C_i + \{j'\}$

$C_{i''} \leftarrow C_{i''} + \{j'\}$

end if

Until ($Sd_i \leq Cap_i$ **)**

end if

end for

end if

end for

return the repaired chromosome

Fig. 4. Chromosome repairing procedure

E. Solution cost

In order to obtain a solution cost, the procedure presented in Fig. 5. is proposed, it also allows deducing the vehicle routing organization; For each depot, as long as the capacity of the vehicle allows, the closest customer to the last one of the tour is added, once no more customers can be added, the vehicle returns to the depot, and another tour begins via another vehicle of the same depot fleet, it begins from the nearest customer of the depot which is not yet visited.

This procedure allows to obtain and to optimize the depots opening costs and the routing costs.

The function $Add(T_{im}, j)$ adds the node j at the end of the tour T_{im} via the vehicle v_{im} .

Procedure: SolCost
Input : A solution S
Output : Solution S cost

$Ct \leftarrow 0$

for each $i \in Dep$ **do**

if ($ds(i) \neq 0$ **) then**

$Ct \leftarrow O_i$

$j \leftarrow$ index of first customer affected to i

$m \leftarrow 1$

repeat

$Add(T_{im}, j)$

$Ct \leftarrow Ct + vc_{im}$

$cpv_{im} \leftarrow cpv_{im} - d_j$

$C_i \leftarrow C_i - \{j\}$

$C_i' \leftarrow C_i - \{j\}$

$Ct \leftarrow Ct + c_{ij}$

repeat

$j' \leftarrow Close(j, C_i')$

if $(d_{j'} < cpv_{im})$ **then**

$Add(T_{im}, j')$

$cpv_{im} \leftarrow cpv_{im} - d_{j'}$

$Ct \leftarrow Ct + c_{jj'}$

$C_i \leftarrow C_i - \{j'\}$

$C_i' \leftarrow C_i' - \{j'\}$

else

$C_i' \leftarrow C_i' - \{j'\}$

end if

until $(C_i' = 0)$

$Ct \leftarrow Ct + c_{j'i}$

$j \leftarrow Close(i, C_i)$

$m \leftarrow m + 1$

until $(C_i = 0)$

end if

end for

Return the total cost of the solution, Ct

Fig. 5. The procedure to obtain a solution cost

F. Local search

The Local Search allows improving a solution by exploring its neighborhood, for this, four movements are used and presented in the sequel, each is illustrated by an example. The movements are applied to customers that can belong to the same tour or from different tours. Tours can belong to the same depot or to different ones, for each case the constraints are presented. Fig. 10. describes the steps of the procedure, the neighborhood of a solution is explored and the procedure returns the best solution and its cost.

In the sequel, S is a solution, Sd_i is the sum of demands that provides the depot i and Qt_{im} is the amount transported during a tour via the vehicle v_{im}

RouteTrans (S, i, i', m)**:** a random tour T_{im} is transferred from its current depot i to the best opened one i'. Constraint (1) ensures that the capacity of the depot to which a tour is transferred is respected.

$$Cap_{i'} \geq Sd_{i'} + Qt_{im} \quad (1)$$

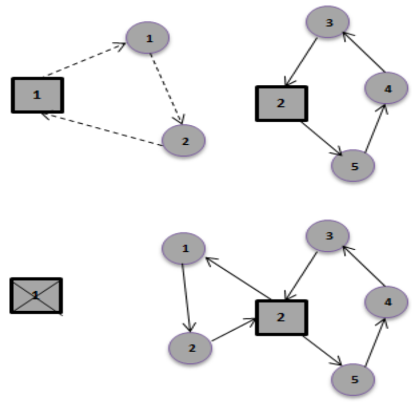

Fig. 6. Example of a RouteTrans operator

CustTrans (S,i,i',m,m',j,j') **:** a customer j, randomly selected, is transferred from its current position in a tour m to another position after a node j' in a tour m' that may be in the same route $(i=i'$ and $m=m')$ in another one from the same depot $(i=i'$ and $m\neq m')$ or from another route from another depot $(i\neq i'$ and $m\neq m')$. Constraints (2) and (3) ensure that both capacities of the vehicle and the depot, to which a customer is transferred, are respected.

$$cpv_{m'i'} \geq Qt_{i'm'} + d_j \quad (2)$$

$$Cap_{i'} \geq Sd_{i'} + d_j \quad (3)$$

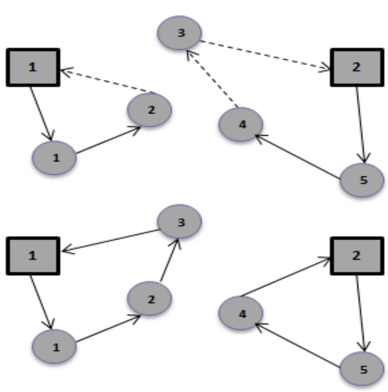

Fig. 7. Example of a CustTrans operator

CustSwap (S,i,i',m,m',j,j') **:** two customers randomly selected j and j' are exchanged, they may be in the same route $(m=m')$ or in different routes $(m\neq m')$ from the same depot $(i=i')$ or different depots $(i\neq i')$. Constraints (4)-(7) ensure that both capacities of the vehicles and the depots, to which customers are transferred are respected.

$$cpv_{i'm'} \geq Qt_{i'm'} + d_j - d_{j'} \quad (4)$$

$$cpv_{im} \geq Qt_{im} + d_{j'} - d_j \quad (5)$$

$$Cap_{i'} \geq Sd_{i'} + d_j - d_{j'} \quad (6)$$

$$Cap_i \geq Sd_i + d_{j'} - d_j \quad (7)$$

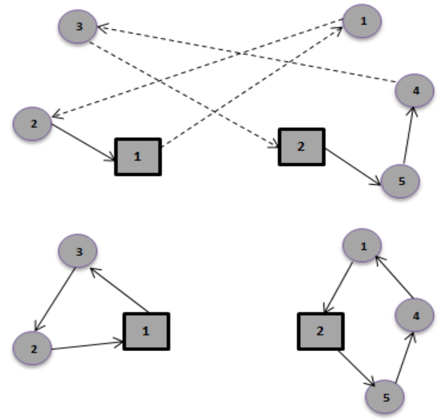

Fig. 8. Example of a CustSwapoperator

Opt (S,i,m,m',j,j') **:** the edges incoming to nodes j and j' are deleted and two new edges are created, tours begin from the same depot i and edges may be in the same tour $(m=m')$ or in different tours $(m\neq m')$. Constraints (8)-(11) ensure that both capacities of the new tours' vehicles and their departure depots are respected.

$$cpv_{im} \geq Qt_{im} + d_{j'} - d_j \quad (8)$$

$$cpv_{i'm'} \geq Qt_{i'm'} + d_j - d_{j'} \quad (9)$$

$$Cap_i \geq Sd_i + d_{j'} - d_j \quad (10)$$

$$Cap_{i'} \geq Sd_{i'} + d_j - d_{j'} \quad (11)$$

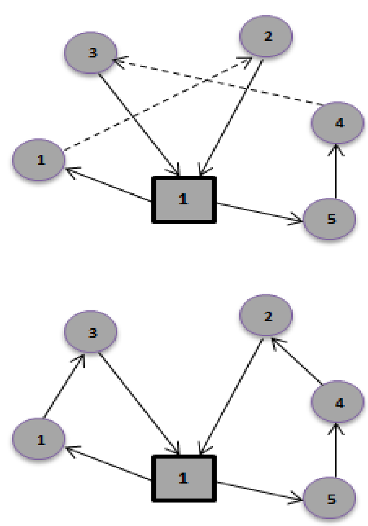

Fig. 9. Example of an Opt operator

Procedure: Localsearch
Input : A solution S
Output : S_{best}

$S_{best} \leftarrow S$; $S_{\min} \leftarrow S$

$N_{RT} \leftarrow \varnothing$; $N_{CT} \leftarrow \varnothing$; $N_{CS} \leftarrow \varnothing$; $N_{OPT} \leftarrow \varnothing$

$N_{RT} \leftarrow S$ neighborhood generated using RouteTrans operator

$N_{CT} \leftarrow S$ neighborhood generated using CustTrans operator

$N_{CS} \leftarrow S$ neighborhood generated using CustSwap operator

$N_{OPT} \leftarrow S$ neighborhood generated using Opt operator

$S_{\min} \leftarrow \arg\min \{ SolCost(S) / S \in N_{RT} \cup N_{CT} \cup N_{CS} \cup N_{OPT} \}$

Repair $S_{\min}$ using ChromRepair procedure

if $SolCost(S_{\min}) \prec SolCost(S_{best})$ then

$S_{best} \leftarrow S_{\min}$

end if

Return S_{best} and $SolCost(S_{best})$

Fig. 10. The local search procedure

G. The memetic algorithm

The memetic algorithm is obtained by gathering the components previously presented, it starts with generating an initial population using GenInitialSol procedure, a maximum number of generations $\max gen$ is fixed , as long as the latter is not reached the selection and the crossover are repeated, each child obtained is repaired with ChromRepair procedure, if it does not already belong to the population it is improved using LocalSearch procedure with a probability p_{ls} and replaces the worst element of the population, once $\max gen$ is reached, the procedure returns the best solution of the last obtained population. The Local Search is applied only once to each offspring, which allows exploring its neighborhood, applying it several times would take a lot of time and would lead to the local optimum.

Procedure: MemeticAlgorithm
Input : Problem data
Output : Best solution P_{best}

$t \leftarrow 0$

Initialize population $P(t)$ using GenInitialSol procedure

while ($t < \max gen$) **do**

Select parents p_1 and p_2 using binary tournament

Cross p_1 and p_2 to obtain child c

Repair c using ChromRepair procedure

If $c \in P(t)$ **then**

Repeat selection and crossover

else

Apply LocalSearch procedure to c with a probability p_{ls} to obtain c'

if $c' \notin P(t)$ **then**

remove worst solution from $P(t)$ and add c' to $P(t)$

end if

$t \leftarrow t+1$

end while

Return P_{best}

Fig. 11. General structure of the memetic algorithm

IV. Computational Experiments

In order to investigate the performance of the algorithm, test instances presented by Prodhon [28] for the CLRP are used, which consists of capacitated depots and routes, the number of potential depots is $N_d \in \{5,10\}$, the number of customers to serve is $N_c \in \{20, 50, 100, 200\}$, and vehicle capacity is in $\{70,150\}$. The depots opening costs vary from one depot to another, yet, the cost of use of a vehicle remains the same for all. After preliminary testing, p_{ls} is fixed to 0.6, $\max gen$ to $(N_d + N_c) * 20$ and the population size is $N_d + N_c$. Procedures are implemented in C language on an Acer Aspire ONE D255 1.00 GHz machine, running Windows 7 Starter Edition.

Table. 1. Provides a comparison between the results obtained by the proposed memetic algorithm and those obtained by the GRASP proposed by Prodhon, Podhon's set consists of 30 instances, results are given on average by instances size. For each case, the number of depots to open, the number of tours and the solution cost are presented. The gap between the two algorithms is obtained by calculating [(MA cost - GRASP cost)/ GRASP cost]*100. As shown in the table, good quality solutions are obtained by MA, it presents a gain in term of cost which is in average of 1.08%. The best improvements have been obtained for the large sizes where the gain reaches 2.73%. Both MA and GRASP returns the same number of depots to be opened, MA uses one less vehicle on certain instances from 100 customers, costs are reduced thanks to the opened depots location and not to their number, MA provides access to diverse solutions of good quality, which allows obtaining lower cost solutions.

TABLE I. COMPUTATIONAL RESULTS OF THE MEMETIC ALGORITHM

Number of potential depots	Number of customers	GRASP			MA			Gap
		Number of opened depots	Number of tours	cost	Number of opened depots	Number of tours	cost	
5	20	2.5	4	45144	2.5	4	45301	0.35
5	50	2.62	9	74701	2.62	9	74685	0.02
5	100	2.33	16	202210	2.33	15.83	201303	0.45
10	100	3.33	18.33	257048	3.33	17.66	250040	2.73
10	200	3	35	447657	3	34.5	436293	2.54
Average		2.76	16.47	205352	2.76	16.2	201524.4	1.08

V. CONCLUSION

This paper treats a location-routing problem where both potential depots and vehicles have limited capacities. A memetic algorithm is developed to solve the problem which objectives are to minimize the total cost of distribution and meet the customers' needs. The algorithm is tested on instances of the literature and compared to a GRASP. The proposed algorithm provides obtaining good quality solutions, it may be used to obtain a good initial solution to exact methods.

REFERENCES

[1] S. Salhi, and G. K. Rrand, "The effect of ignoring routes when locating depots," in European Journal of Operational Research, vol. 39, no. 2, pp. 150–156, 1989.

[2] J. H. Lee, I. K. Moon, and J. H. Park, "Multi-level supply chain network design with routing," in International Journal of Production Research, vol. 48, no. 13, pp. 3957–3976, 2010.

[3] G. List, and P. Mirchandani, "An integrated network/planar multiobjective model for routing and siting for hazardous materials and wastes," in Transportation Science, vol. 25, no. 2, pp. 146–156, 1991.

[4] T. H. Wu, C. Low, and J. W. Bai, "Heuristic solutions to multi-depot location-routing problems," in Computers and Operations Research, vol. 29, pp.1393–1415, 2002.

[5] S. C. Liu, and S. B. Lee, "A two-phase heuristic method for the multi-depot location routing problem taking inventory control decisions into considerations," in International Journal of Advanced Manufacturing Technology, vol. 22, pp. 941–950, 2003.

[6] G. Nagy, and S. Salhi, "Location-routing: Issues, models and methods," in European Journal of Operational Research, vol. 177, no. 2, pp. 649–672, 2007.

[7] G. Laporte, Y. Norbert, and D. Arpin, "An exact algorithm for solving a capacitated location-routing problem," in Annals of Operations Research, vol. 6, pp. 293–310, 1986.

[8] R. Baldacci, A. Mingozzi, and R.W.Calvo, "An exact method for the capacitated location-routing problem," Operations Research, vol. 59, no. 5, pp. 1284–1296, 2011.

[9] C. Contardo, J. F. Cordeau, and B. Gendron, "An exact algorithm based on cut-and-column generation for the capacitated location-routing problem," in INFORMS Journal on Computing, vol. 26, no. 1, pp. 88–102, 2014.

[10] C. Prins, C. Prodhon, and R. Calvo, "Solving the capacitated location-routing problem by a GRASP complemented by a learning process and a path relinking," in 4OR: A Quarterly Journal of Operations Research, vol. 4, pp. 221–238, 2006.

[11] C. Duhamel, P. Lacomme, C. Prins, and C. Prodhon, "A GRASP × ELS approach for the capacitated location-routing problem," Computers and Operations Research, vol. 37, no. 11, pp. 1912–1923, 2010.

[12] C. J. Ting, and C. H. Chen, "A multiple ant colony optimization algorithm for the capacitated location-routing problem," in International Journal of Production Economics, vol. 141, no. 1, pp. 34–44, 2013.

[13] C. Prins, and C. Prodhon, "A survey of recent research on location-routing problems," in European Journal of Operational Research, vol. 238, no. 1, pp. 1–17, 2014.

[14] J. Y. Potvin, "Genetic Algorithms for Traveling Salesman Problem," in Annals of Operations Research, vol. 63, no. 3, pp 337–370, 1996.

[15] F. G. Zhao, J. S. Sun, S. J. Li, and W. M. Liu, "A hybrid genetic algorithm for the traveling salesman problem with pickup and delivery," in International Journal of Automation and Computing. vol. 6, no. 1, pp. 97–102, 2009.

[16] C. Prins, "A simple and effective evolutionary algorithm for the vehicle routing problem," in Computer and Operations Research, vol. 31, no. 12, pp. 1985–2002, 2004.

[17] T. Vidal, T. G. Crainic, M. Gendreau, and W. Rei, "A hybrid genetic algorithme for multi-depot and periodic vehicle routing problems," in Operations Research, vol. 60, no. 3, pp. 611–624, 2012.

[18] C.R. Reeves, "Genetic algorithms," in handbook of metaheuristics, International series in operations research and management science, 2nd ed., Springer, 2010, pp. 109–140.

[19] P. Moscato, "On evolution, search, optimization, genetic algorithms and martial arts: Towards memetic algorithms," in Technical Report C3P 826, Cal-teech Concurrent Computation Program, 1989.

[20] N. Krasnogor, and J. Smith, "A tutorial for competent memetic algorithms : model, taxonomy, and design issues," IEEE Transactions on Evolutionary Computation, vol. 9, no. 5, pp. 474–488, 2005.

[21] F. Neri, and C. Cotta, "Memetic algorithms and memetic computing optimization: A literature review," in Swarn and Evolutionary Computation, vol. 2, pp. 1–14, 2012.

[22] M. Freizleben, and P. Mertz, "Memetic Algorithms for the Traveling Salesman Problem," in Complex Systems, vol. 13, pp. 297–345, 2001.

[23] D. Cattaruzza, N. Absi, and D. Feillet, "A memetic algori.thm for the multi trip vehicle routing problem," in European Journal of Operational Research, vol. 236, issue. 3, pp 833–848, 2014.

[24] J. Mendoza, B. Castanier, C. Gueret, A. Medaglia, and N. Velasco, "A memetic algorithm for the multi-compartment vehicle routing problem with stochastic demands," in Computers and Operations Research, vol. 37, issue. 11, pp. 1886–1898, 2010.

[25] C. Prins, "Two memetic algorithms for heterogeneous fleet vehicle routing problems," in Engineering Applications of Artificial Intelligence, vol. 22, pp. 916–928, 2009.

[26] C. Lima, M. Goldberg, and E. Goldberg, "A memetic algorithm for heteregenous fleet vehicle routing problem," in Electronic Notes in Mathematics, vol. 18, pp. 171–176, 2004.

[27] K. Sörensen, and M. Sevaux, "MA/PM : Memetic algorithms with population management," in Computers and Operations Research, vol. 33, pp. 1214–1225, 2006.

[28] C. Prins, C. Prodhon, and R. Calvo, "A memetic algorithm with population management (MA/PM) for the capacitated location-routing problem," in Evolutionary computation in combinatorial optimization, J. Gottieb, G. Raidl, Eds. Berlin/Heidelberg: Springer, 2006, pp. 183–94.

Design and Modeling of RF Power Amplifiers with Radial Basis Function Artificial Neural Networks

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***Abstract*—A radial basis function (RBF) artificial neural network model for a designed high efficiency radio frequency class-F power amplifier (PA) is presented in this paper. The presented amplifier is designed at 1.8 GHz operating frequency with 12 dB of gain and 36 dBm of 1dB output compression point. The obtained power added efficiency (PAE) for the presented PA is 76% under 26 dBm input power. The proposed RBF model uses input and DC power of the PA as inputs variables and considers output power as the output variable. The presented RBF network models the designed class-F PA as a block, which could be applied in circuit design. The presented model could be used to model any RF power amplifier. The obtained results show a good agreement between real data and predicted values by RBF model. The results clearly show that the presented RBF network is more precise than multilayer perceptron (MLP) model. According to the results, better than 84% and 92% improvement is achieved in MAE and RMSE, respectively.**

Keywords—Amplifier model; artificial neural network (ANN); class-F amplifier; radial basis function; RF amplifier

I. Introduction

PAs are important elements, in any communication system, which consume a lot of power. Therefore, the efficiency is a very important factor in the design process. Considerable energy can be saved, by improving the efficiency of PAs [1-2]. The switching mode amplifiers are introduced to achieve high efficiency. Class-F PAs have become very popular in switching mode amplifiers, because of their high efficiency and output capability [3-5]. In the class-F PAs, Ideal drain efficiency could be obtained, due to the optimum drain voltage and drain current waveforms shape. Several methods have been introduced to model power amplifiers, such as Wiener [6] and Volterra series [7]. However, these mentioned models need approximation for obtaining the specifications of the device. Neural network based models are faster and more precise, compared with the mentioned modeling methods [8]. Any continuous nonlinear function could be approximated using ANNs. Therefore, ANNs can be used to model nonlinear circuits [9].

Power amplifiers are recently modeled, using artificial neural networks algorithms [10-12]. In [10], adaptive neuro-fuzzy inference system (ANFIS) is presented to model a PA. In this model, memory effect of the amplifier is not considered; however, the presented structure of the ANFIS is complicated. An ANN is used in [11] to model a 3G power amplifier. A large number of neurons are applied in this ANN, which makes the model complex. In this approach, the power spectral density (PSD) is obtained, however the other specifications of the power amplifier are not considered. Neural networks have also been used to model the other microwave components [12-15]. In [12] a lowpass microstrip filter is modeled using multilayer perceptron (MLP) neural network with two hidden layers. The presented model in this research is used to predict the specifications of a lowpass microstrip filter; however, the applied model in this work is complex and uses a large number of neurons. A low voltage microwave LNA with operating frequency of 2.45 GHz is modeled in [13]. In this approach MLP, RBF and ANFIS models are investigated and the small signal parameters are considered as the input of the networks. Channel dimensions of the transistors are considered as the output of the networks. However, the presented model can only be used in the applied circuit. In [16] a microstrip patch antenna is modeled and designed using RBF network. The results in this approach show that RBF network model is more accurate than the MLP network.

An efficient class-F amplifier is modeled by neural networks in [15]. The presented ANN model in this paper can predict the efficiency and output power of the amplifier. The MLP neural network training method for ANN is used in this research. The reported errors are acceptable, but it can be improved using other ANN methods.

Recently, the RBF networks have been used to model several microwave devices [17-18]. However they have not been applied to model power amplifiers in the way, which is used in this paper.

In this paper, at first a class-F switching amplifier is designed and simulated. Then, an RBF network is proposed to model the designed amplifier precisely. Finally, the presented model is compared with the conventional MLP ANN, which shows better performances. The presented model can be used as a sub-circuit model to describe the class-F power amplifier applications. For instance, it can be used in linearization method or Doherty power amplifier structures.

II. Design of Power Amplifier

Figure 1 shows the basic structure of the presented class-F PA, including a transistor, input/output matching network and DC supply voltage. The output matching network includes a parallel resonator circuit and a quarter wavelength transmission line [19]. The output network shapes the drain voltage and current waveforms to improve the efficiency [20]. Therefore, the output becomes short circuit in even harmonics, while it becomes open circuit in odd harmonics. The process of drain waveforms shaping improves the efficiency of class-F PA. There are one or more odd harmonics in voltage of the drain, such that it becomes approximately a square wave. In the contrary, even harmonics in the current of the drain make approximately a half sinusoidal waveform.

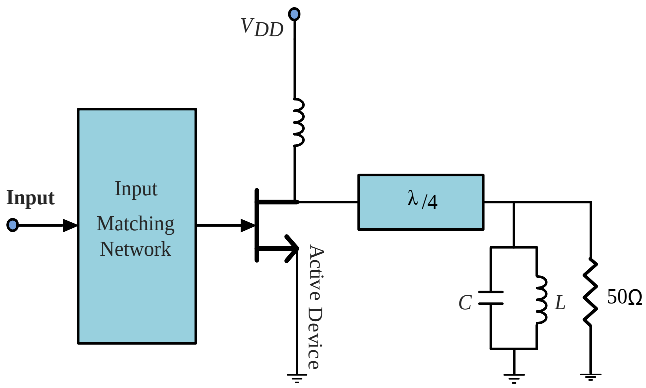


Fig. 1. Fundamental structure of the class-F PA

The designed matching circuit for the presented amplifier is shown in Fig. 2. According to this figure the applied microstrip transmission lines are shown as T1 – T10, which are used as harmonic control circuits. The power relations and the power added efficiency for the presented amplifier could be given as

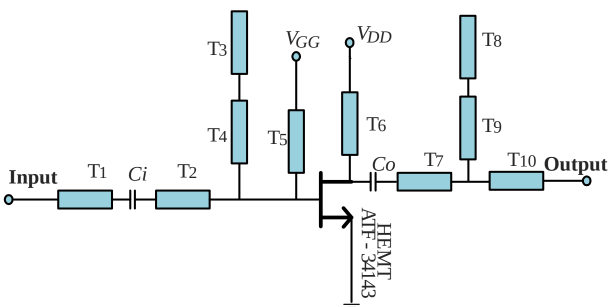


Fig. 2. Structure and matching networks of the designed amplifier

$$PAE = \frac{P_{output} - P_{input}}{P_{DC}} \tag{1}$$

$$P_{DC} = V_{DC} I_{DC} \tag{2}$$

$$P_{output} = \frac{V_m^{\ 2}}{2R}. \tag{3}$$

In above equations P_{output} and P_{DC} are output power and DC power, while P_{input} is the input signal power. PAs convert the DC power and power of the input signal into output AC power. According to Fig. 2, an ATF 34143 HEMT is applied in the designed PA circuit. Simulation is carried out by advanced design system (ADS) software, which contains the device model. According to simulation results, P1dB of 36 dBm is obtained. Also, the power gain and maximum PAE are 12 dBm and 76% under the 26 dBm input power. In the next section, MLP and RBF networks will be introduced. Then, an RBF neural network model will be applied to the designed amplifier. The input and DC power of the power amplifier are assumed as input variables for the RBF network, while the output power is assumed as the output variable for the RBF network.

III. MLP AND RBF MODELS

ANN can be considered as a mathematical system consisting of simple processing elements called neurons. These neurons can be aligned in one or multiple layers. The MLP and RBF networks are the common architectures in neural networks. The MLP feed forward network has three layers, which the first and the second are the input layer and the hidden layer. The third layer is the output layer. There are several neurons in each layer of the network and the connections between them are weighted connections. The values of weights in each layer are obtained using training algorithm, which is commonly back propagation algorithm. Applying more neurons or more layers to the network may increase the precision of the model, but it cost complexity of the network and subsequently more time is needed to simulate the presented model.

The RBF network, introduced in 1988, is a feed forward ANN. The RBF network is an artificial neural network with radial basis activation functions, including three layers in the structure. The layers of the RBF network are similar to MLP network, but there is one hidden layer in the RBF network. Source nodes are in the input layer, and there are several neurons in the second layer (hidden layer), which are called the RBF centers. The outputs of the hidden neurons are summed, by the neurons in the output layer. Activation function of the units in the second layer is radial basis function. The structure of the typical RBF ANN is illustrated in Fig. 3, including two inputs and three layers. Input layer includes input nodes with the same number as the number of input vector [21]. The i^{th} neuron output in the hidden layer could be given as

$$q_i = \exp\left(-\frac{\left\| X_i - C_i \right\|^2}{\sigma_i^{\ 2}} \right), \tag{4}$$

where X is input vector, C is basis function center and σ_i is spread of Gaussian function. The estimated output can be written as0

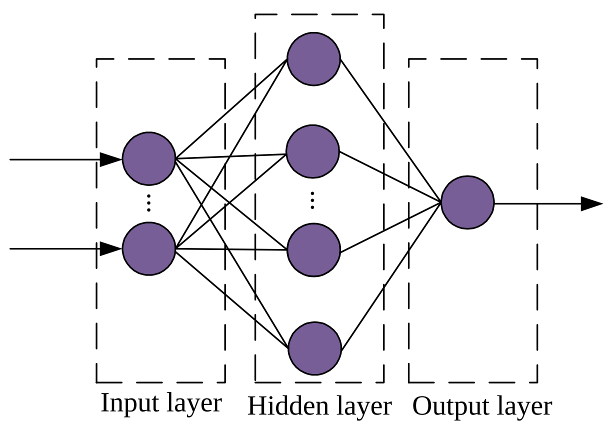
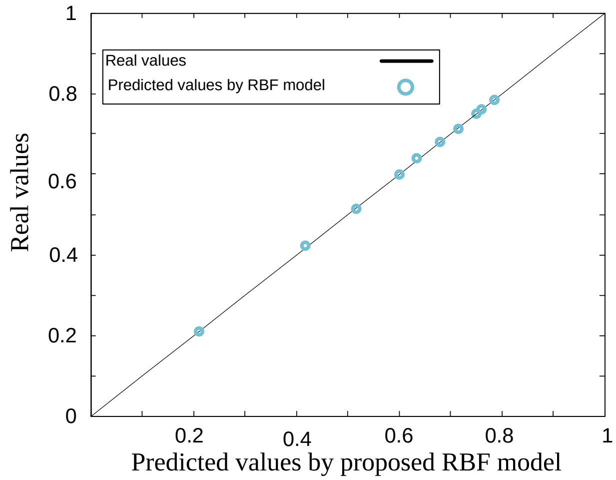
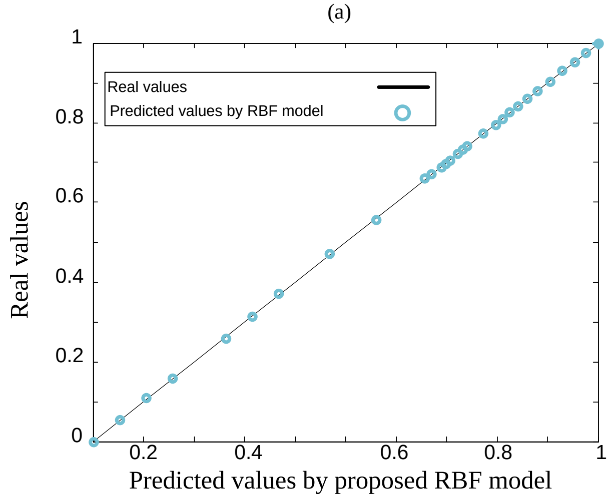


Fig. 3. Structure of the RBF ANN



(a)



(b)

Fig. 4. Real and predicted output power results of (a) testing data and (b) training data, using RBF model

$$y = \sum_{i=1}^{n} w_i q_i \qquad (5)$$

The connecting weights are shown with w_i in equation (5). The input power and DC power are assumed as input variables of the network, while, the output power is assumed as the output variable of the network. About 75 percent of data set is used for training, while 25 percent is used for testing process of the proposed model in RBF network. Detailed results of the RBF network are given in Table 1. The mean absolute error (MAE) and also the root mean square error (RMSE) for the presented network are given as

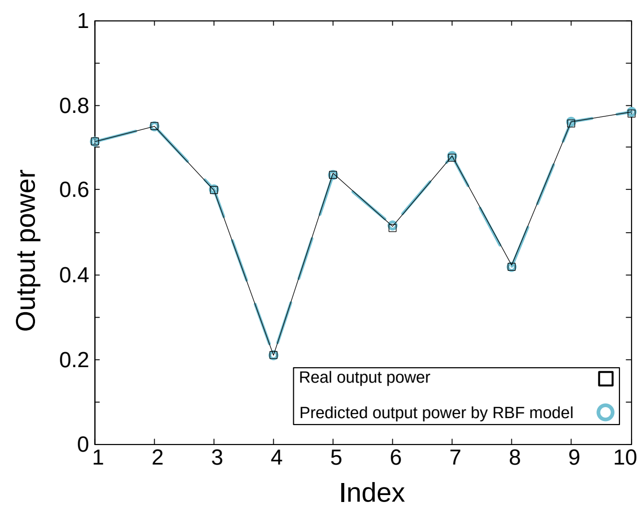
$$MAE\,\% = 100 \times \frac{1}{N}\sum_{i=1}^{N}\left|Y_{Ri} - Y_{Pi}\right| \qquad (6)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(Y_{Ri} - Y_{Pi})^2}{N}} \qquad (7)$$

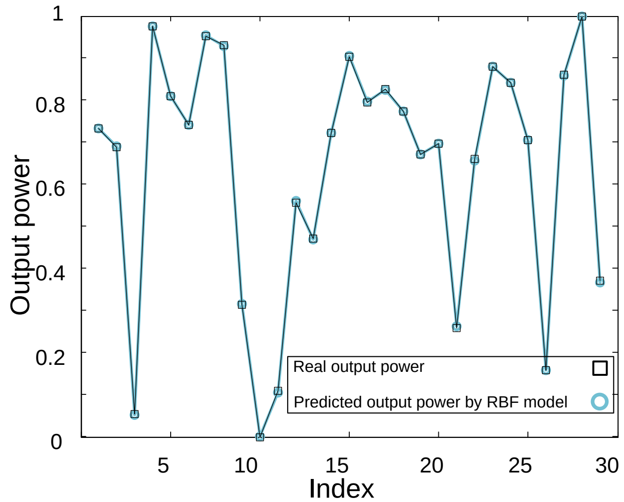
where N is data number. The parameters Y_{Ri} and Y_{Pi} represent the real and predicted output of the presented ANN, respectively. A comparison between real and predicted output power results of training and testing data for the RBF network is illustrated in Fig. 4. Obtained errors of the presented RBF model, compared to the MLP model are summarized in Table 1. The MAE and the RMSE errors of the RBF network could be achieved using equations (6) and (7), respectively.

Real and predicted output power of the PA versus index number of each input for testing and training data using RBF network are illustrated in Fig. 5. According to Figs. 4 and 5, the predicted output power by RBF model is close to the real results. These results verify the accurate applicability of RBF network as a reliable model to predict the output power, using the input and DC power.

Real and predicted output power versus input power for training and testing data are depicted in Fig. 6. As shown in the figure, the presented amplifier is modeled precisely using the proposed RBF network. The real and predicted PAE versus input power for training and testing data are depicted in Fig. 7. Only data in the operating range of the presented amplifier are illustrated in Figs. 6 and 7. As shown, the main specifications of the designed amplifier are predicted using the presented model. Test and train data of the proposed RBF network are given in Table 2 and Table 3, respectively. Input power and DC power, which are the inputs of the network are shown in the first and second columns, while real output power and network predicted out power are compared in third and fourth columns. The predicted data have negligible deference with the real data, which verifies the presented model. 39 samples are selected for the network, which about 75% of the samples are considered for training and 25% are chosen for testing process of the proposed RBF network.



(a)



(b)

Fig. 5. Real and predicted output power of the PA versus index number of each input for (a) testing data and (b) training data, using RBF model

TABLE I. THE OBTAINED ERRORS OF THE PROPOSED RBF NETWORK

Error	Train data	Test data	Test data
	RBF	RBF	ANN[15]
RMSE	0.001	0.002	0.0275
MAE%	0.131	0.311	1.9882

TABLE II. TEST DATA OF THE PROPOSED RBF NETWORK

	Input Power [dBm]	DC Power [dBm]	Output Power [dBm]	Network Output [dBm]
1	30.0000	37.2200	36.6700	36.6764
2	33.9967	37.4800	37.2400	37.2372
3	21.9866	36.3500	34.9000	34.8896
4	13.9967	34.0700	28.8400	28.8136
5	22.9885	36.6300	35.4400	35.4966
6	20.0000	35.7700	33.5900	33.5471
7	25.9988	36.9400	36.1400	36.1266
8	17.9934	35.1900	32.0700	32.1251
9	34.9969	37.5500	37.4000	37.4027
10	36.9984	37.6900	37.7700	37.7695

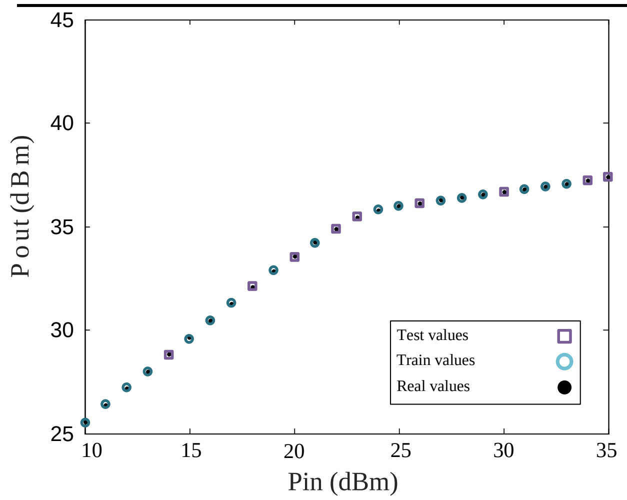


Fig. 6. Real and predicted output power versus input power for training and testing data

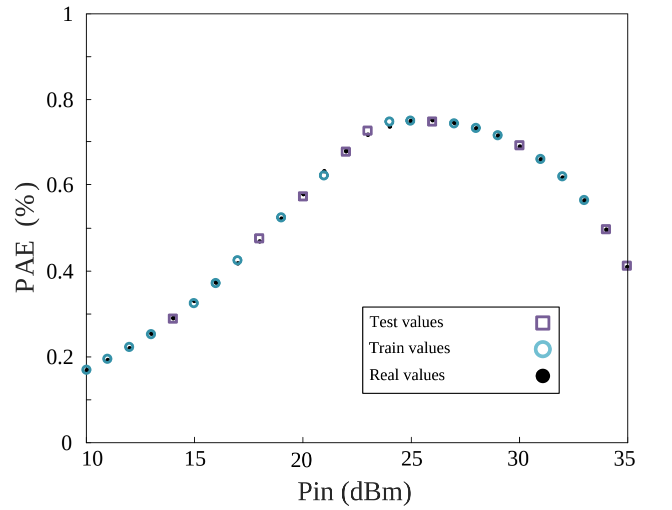


Fig. 7. Real and predicted PAE versus input power for training and testing data

IV. CONCLUSION

An RBF network is proposed to model a linear class-F PA. Input power, DC power and output power of the PA are assumed as input and output variables of the RBF model. The RBF model results are compared with the MLP model. Normalization process is performed on the data set to enhance the accuracy of the presented model. The MAE and RMSE of 0.311 and 0.002 for the RBF network are obtained, respectively. Better than 84% and 92% improvements in MAE% and RMSE have been achieved, so, the proposed RBF network is more accurate than the MLP model. According to the reliability of the presented model, it can be used to model the designed PA as a block or a sub circuit for circuit design. The same procedure can be performed on the other RF and microwave components to achieve their artificial neural network model. Modeling of the other microwave components and amplifiers using the presented procedure will be addressed in the future work.

TABLE III. TRAIN DATA OF THE PROPOSED RBF NETWORK

	Input Power [dBm]	DC Power [dBm]	Output Power [dBm]	Network Output [dBm]
1	31.9866	37.3500	36.9400	36.9439
2	26.9984	37.0100	36.2800	36.2652
3	10.9691	33.4000	26.3800	26.4053
4	46.9984	38.9500	40.7300	40.7333
5	38.9982	37.7600	38.1600	38.1523
6	32.9885	37.4100	37.0800	37.0805
7	45.9988	38.7400	40.3900	40.3777
8	44.9969	38.5800	40.0100	40.0356
9	15.9988	34.5800	30.4600	30.4481
10	10.0000	33.1600	25.5700	25.5395
11	11.9866	33.6300	27.2000	27.2480
12	20.9691	36.0500	34.2700	34.2050
13	18.9982	35.4900	32.8500	32.8733
14	30.9691	37.2800	36.8000	36.8003
15	43.9967	38.4400	39.6300	39.6099
16	37.9934	37.6900	37.9600	37.9284
17	40.0000	37.8800	38.3900	38.4088
18	35.9988	37.6200	37.5800	37.5798
19	24.9969	36.8700	35.9800	35.9862
20	27.9934	37.0800	36.4100	36.4024

21	14.9969	34.3000	29.6500	29.5788
22	23.9967	36.7900	35.7700	35.8245
23	42.9885	38.2900	39.2400	39.2297
24	40.9691	38.0100	38.6400	38.6578
25	28.9982	37.1500	36.5400	36.5393
26	12.9885	33.8400	28.0200	28.0082
27	41.9866	38.1700	38.9200	38.9260
28	47.9996	39.1800	41.1100	41.1095
29	16.9984	34.8900	31.2700	31.3330

REFERENCES

[1] S.Y. Zheng, Z.W. Liu, Y.M. Pan, Y. Wu, W.S. Chan and Y. Liu, "Bandpass Filtering Doherty Power Amplifier With Enhanced Efficiency and Wideband Harmonic Suppression," IEEE Transactions on Circuits and Systems I: Regular Papers 63 (2016) 337-346. doi: 10.1109/TCSI.2016.2515419.

[2] R. Jos, "RF Monte Carlo calculation of power amplifier efficiency as function of signal bandwidth," International Journal of Microwave and Wireless Technologies 8 (2016) 125-133 doi: 10.1017/S175907871500015X.

[3] Y. Ding, Y. X. Guo and F.L. Liu, "High-efficiency concurrent dual-band class-F and inverse class-F power amplifier," Electron. Lett. 47 (2011) 847–849, doi:10.1049/el.2011.1662.

[4] S. Gao, "High efficiency class-F RF/microwave power amplifiers," IEEE Microw. Mag. 7 (2006) 40–48, doi:10.1109/MMW.2006.1614233.

[5] K. Chen and D. Peroulis, "A 3.1-GHz class-F power amplifier with 82% power-added-efficiency," IEEE Microw. Wirel. Compon. Lett. 23 (2013) 436–438, doi:10.1109/LMWC.2013.2271295.

[6] N. Dawar, T. Sharma, R. Darraji, and F.M. Ghannouchi, "Linearisation of radio frequency power amplifiers exhibiting memory effects using direct learning-based adaptive digital predistoriton," IET Communications 10 (2016) 950-954, doi: 10.1049/iet-com.2015.1048.

[7] X. Zheng, L. Su, S. Hu, Z. Ye and J. He, "Legendre wavelet for power amplifier linearization," Analog Integrated Circuits and Signal Processing 84 (2015) 283-292, doi:10.1007/s10470-015-0544-9.

[8] G. Antonini, and A. Orlandi, "Gradient evaluation for neural networks based electromagnetic optimization procedures," IEEE Trans. Microw. Theory Techn. 48 (2000) 874–876, doi:10.1109/22.841892.

[9] S. Haykin, Neural Networks, 2nd edn. (Upper Saddle River, NJ Prentice- Hall, 1999).

[10] K. C. Lee and P. Gardner, "Neuro-fuzzy approach to adaptive digital predistortion," Electron. Lett. 40 (2004) 185–187, doi:10.1049/el:20040154.

[11] T. Liu, S. Boumaiza and M. Ghannouchi, "Dynamic behavioral modeling of 3G power amplifiers using real-valued time-delay neural networks," IEEE Trans. Microw. Theory Tech. 52 (2004) 1025–1033, doi:10.1109/TMTT.2004.823583.

[12] M. Hayati and A. Lotfi, "Modeling of compact microstrip resonator using neural network: Application to design of compact low pass filter with sharp cutoff frequency," Microw. Opt. Techn. Let. 53 (2011), doi:10.1002/mop.26008.

[13] G. H. Karimi, S. Babaei Sedaghat and R, Banitalebi, "Designing and modeling of ultra low voltage and ultra low power LNA using ANN and ANFIS for Bluetooth applications," Neurocomputing 120 (2013) 504–508, doi:10.1016/j.neucom.2013.04.021.

[14] G. Kothapalli, "Artificial neural networks as aids in circuit design," Microelectr J. 26 (1995) 569–578, doi:10.1016/0026-2692(95)00019-E.

[15] M. Hayati, F. Shamma, S. Roshani and A. Abdipour, "Linearization design method in class-F power amplifier using artificial neural network," J. Comput. Electron. 13 (2014) 943–949, doi:10.1007/s10825-014-0612-x.

[16] A. Mohammad, K. Anil and A. JA, "Design and Analysis of Microstrip Line Feed Toppled T Shaped Microstrip Patch Antenna using Radial Basis Function Neural Network," J. Electr. Eng. Technol. 10 (2015) 634–640, doi:10.5370/JEET.2015.10.2.634.

[17] M. Hui, T. Liu, M. Zhang, Y. Ye, D. Shen and X. Ying, "Augmented radial basis function neural network predistorter for linearisation of wideband power amplifiers," Electronics Letters 50 (2014) 877-879, doi: 10.1049/el.2014.0667.

[18] M. Aneesh, A. Kumar, A. Singh, K. Kamakshi, and J.A. Ansari, "Design and Analysis of Microstrip Line Feed Toppled T Shaped Microstrip Patch Antenna using Radial Basis Function Neural Network," Journal of Electrical Engineering and Technology 10 (2015) 634-640, doi: 10.5370/JEET.2015.10.2.634

[19] F. H. Raab, "An introduction to class-F power amplifiers," RF Design 19 (1996) 79–84.

[20] C. Zhao, J. Liu, F. Shen and Y. Yi, "Low power CMOS power amplifier design for RFID and the Internet of Things," Comput. Electr. Eng. (to be published 2015), doi:10.1016/j.compeleceng.2015.06.006.

[21] A. Panteli, M. Maragoudakis, and S. Gritzalis, "Privacy preserving data mining using radial basis functions on horizontally partitioned databases in the malicious model," Int. J. Artif. Intell. Tools 23 (2014) 1450007, doi:10.1142/S021821301450007

Denial of Service Attack in IPv6 Duplicate Address Detection Process

An Impact Analysis on IPv6 Address Auto-configuration Mechanism

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***Abstract*—IPv6 was designed to replace the existing Internet Protocol, that is, IPv4. The main advantage of IPv6 over IPv4 is the vastness of address space. In addition, various improvements were brought to IPv6 to address the drawbacks in IPv4. Nevertheless, as with any new technology, IPv6 suffers from various security vulnerabilities. One of the vulnerabilities discovered allows Denial of Service Attack using the Duplicate Address Detection mechanism. In order to study and analyse this attack, an IPv6 security testbed was designed and implemented. This paper presents our experience with the deployment and operation of the testbed, and discussion on the outcome and data gathered from carrying out DoS attack in this testbed.**

Keywords—Duplicate Address Detection; Denial of Service; IPv6; Address autoconfiguration; Security; Internet Protocol

I. Introduction

Internet protocol version 6 (IPv6) [1], was introduced not only to overcome the limitations of an existing Internet protocol version 4 (IPv4) [2] but also be future oriented due to the rapid growth of Internet technologies. Thus, IPv6 is also known as a next generation Internet protocol. In December 1998, Internet Engineering Task Force (IETF) defined this new Internet protocol. In addition, to provide large address space, new features were introduced in IPv6 such as; simpler header format, mobility functions, extension header, as well as address autoconfiguration [1].

One of the main features of IPv6 protocol is address autoconfiguration [3], which means IPv6 host(s) can obtain IP address automatically. Therefore, autoconfiguration can simplify addressing assignment among IPv6 hosts in link local communication as hosts can generate addresses without any intervention. Even though it has eased IP addressing assignment, improper configuration can raise serious security issues. Studies [4-6] have proven that autoconfiguration mechanism is susceptible to security threats like denial of service (DoS) attacks during address autoconfiguration process.

This paper focuses on the impact analysis of denial of service (DoS) attack [7] on duplicate address detection (DAD) [6] process during address autoconfiguration in IPv6 link local network and its consequences. The rest of the paper is organized as follows.

Section II of this article describes the concept of denial of service (DoS) attack and its classifications. Section III explains the address autoconfiguration process in IPv6 link local network, including duplicate address detection (DAD) process and the denial of service attack attempts during DAD process in respective subsections. Section IV presents the design and implementation of testbed setup based on DoS-on-DAD attack. Section V depicts the outcome obtained from the experimental setup. Finally, Section VI concludes this article with future work.

II. Denial of Service attack and its classification

Denial of service (DoS) attack is one of the major security threats to the IPv4 and IPv6 networks [7]. In DoS attacks, a victim host(s) can be denied from the services by wasting its resources and disrupt its communication with other neighboring hosts on same link. A targeted device is unable to process such large amount of network traffic and becomes unavailable or out of service.

Moreover, when DoS attack is being attempted from large networks or systems then it is known as Distributed Denial of Service (DDoS) attacks [7, 8]. In order to perform DDoS attack, an attackers uses various resources such as network nodes and Internet services which are distributed around the globe considered as botnets. Later, these botnets are used to launch the DDoS attack against the targeted victim.

A. Denial of service attacks on IPv6 network

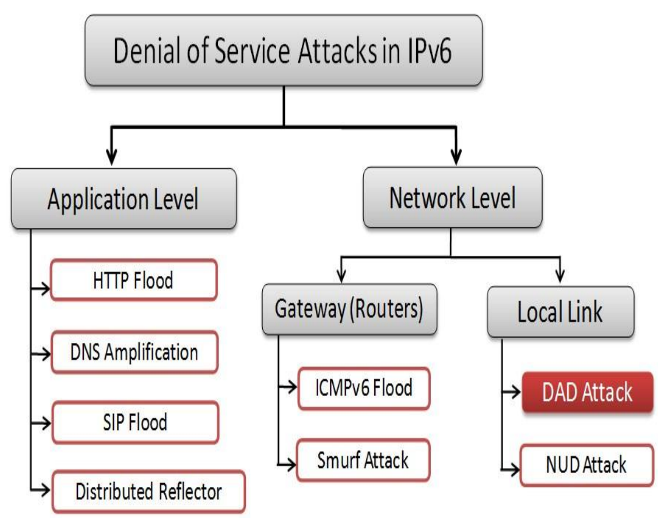


Fig. 1. Taxonomy of DoS attacks in IPv6 network

Denial of Service (DoS) attacks in IPv6 network can be broadly classified into two main categories based on the attacked level such as; application level and network level. Further network level DoS attacks can be subdivided into gateway (router) and local link levels respectively. Figure 1 depicts the taxonomy of DoS attacks in IPv6 network.

During address autoconfiguration in IPv6 link local network, Internet control message protocol (ICMPv6) [9] message types are used by the hosts to communicate with neighboring hosts within a local link. However, studies [10, 11] have shown that ICMPv6 messages are vulnerable to denial of service (DoS) attacks, especially during duplicate address detection (DAD) process while host(s) attempts to configure its own generated interface identifier (IID).

Therefore, an attacker can take an advantage of it and can fabricate these ICMPv6 messages. Later, attacker can exploit these modified messages to generate denial of service (DoS) attacks in a number of ways; either by spoofing the messages, Man-in-the-Middle form or simply sending excessive numbers of bogus ICMPv6 packets to the target host on the local link. Thus, an attacker can disrupt the IPv6 hosts to obtain their interface identifier (IID).

III. Address Autoconfiguration in IPv6 Link Local Network

In IPv6 Link local network, IPv6 host can communicate with other neighboring hosts by using five types of ICMPv6 messages also known as Neighbor Discovery Protocol (NDP) [12] messages are as follows:

- Router Solicitation (RS) message type 133, is send by IPv6 hosts to discover the presence of a neighboring router(s) on local link.
- Router Advertisement (RA) message type 134, is sends by router(s) in reply to a RS message or periodically advertises the RA messages.
- Neighbor Solicitation (NS) message type 135, is send by IPv6 nodes to resolve IPv6 address to its link-layer address (MAC address) or to verify IPv6 node reachability or to perform duplicate address detection.
- Neighbor Advertisement (NA) message type 135, is send by IPv6 nodes in response to a NS message or to advertise a link-layer address change.
- Redirect message type 137, is send by routers in IPv6 Link local communication to advertise better route for a destination.

Neighbor discovery [12], as the name suggests, in IPv6 networks allow the hosts to find the presence and link local addresses of other hosts on the same link. Also, it provides other functionalities such as address resolution, neighbor unreachability detection, router discovery, redirect method for routers to inform IPv6 hosts about the most appropriate router available on the same link and resolve duplicate address detection on the same link .

A. IPv6 Address Autoconfiguration Process

When a new host joins an IPv6 local link network, it goes through a number of operations to configure its own Interface identifier (IID). As IPv6 host connects to local link network, it sends a Router Solicitation (RS) message to a link local router to get the network prefix information. In response, link local router replies with a Router Advertisement (RA) message by sending network prefix. Once the host has gathered that network prefix can now generate its interface identifier (IID) [3].

Afterwards, the host combines the subnet prefix with the IID to form a complete 128 bits IPv6 address which is enough for hosts to communicate within a same link [3]. Finally, an autoconfiguration process verifies its uniqueness on a link by performing a Duplicate Address Detection process [6] that will be discussed in Subsection B. Figure 2 depicts new host address autoconfiguration process in IPv6 link local network.

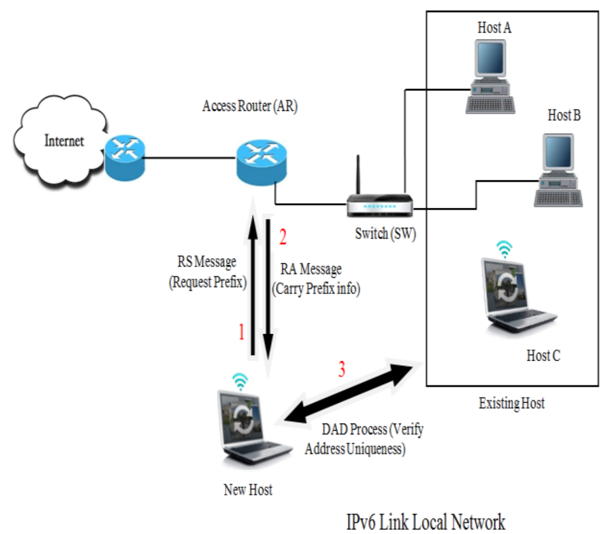


Fig. 2. IPv6 address autoconfiguration process

B. Duplicate Address Detection Process

Duplicate address detection is a mechanism ensuring that all the IPv6 hosts have unique IP addresses by verifying their uniqueness on the same link. Every host must execute DAD process before specifying an address to an interface [6]. When host(s) generate new IP addresses, after generating an interface identifier host(s) ascertain that no other neighboring host(s) already possesses that generated address on the same link to avoid the IP address conflict.

DAD process is being performed by sending Neighbor Solicitation (NS) messages multicast to all neighboring hosts within a same link. These NS messages carry the tentative IP address that the host(s) has generated and would like to assign as its interface identifier. If the tentative address is already assigned by any other neighboring host within a same link, then that neighboring host will send a Neighbor Advertisement (NA) in reply. Hence, new host generates a new tentative address. In next attempt, if a new host does not receive any response to its NS messages from the neighboring nodes; it indicates that the newly generated address is unique and no other neighboring host is using this address. Thus, a host can use that generated address as preferred address as an interface identifier [6]. Figure 3 illustrates the DAD process.

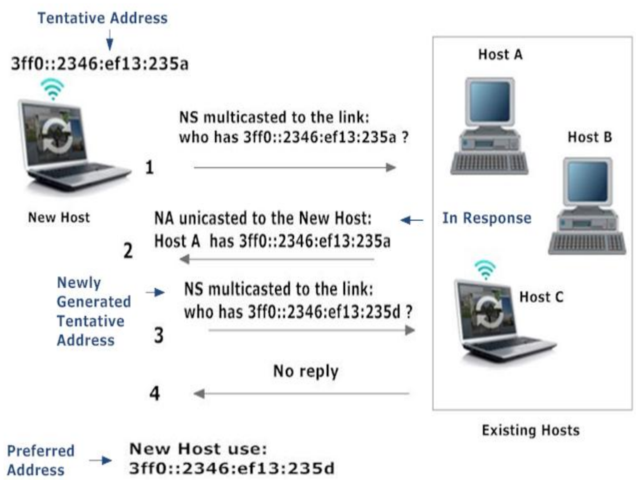


Fig. 3. Duplicate address detection process

C. Denial of Service Attack on DAD Process

During the DAD operation, an attacker can disguise the victim host while attempting to verify its address uniqueness in IPv6 link local communication by using the specific address and responds to every detection message. Thus, it the victim host may be unable to configure its IP address such type of attack is known as DoS on DAD attack. During this attack an attacker can respond to every duplicate address detection attempts made by a newly joining host in IPv6 link local communication. In case an attacker claims addresses, the other host(s) on a same link will never be able to configure an IP address [6]. Figure 4 illustrates the DoS on DAD attack.

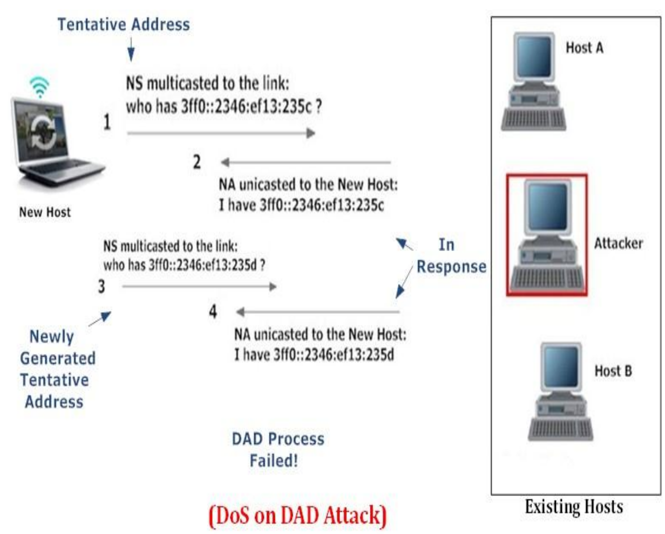


Fig. 4. Denial of service attack on DAD process

IV. Design and Implementation of Testbed Setup

Beginning with the assumptions this section describes the design and implementation of testbed setup scenario for the experiment required. In order to conduct the test on DoS-on-DAD attack in IPv6 networks; a closed IPv6 network setup environment has been deployed at the National Advanced IPv6 Center (NAv6) research Institute, University Sains Malaysia (USM).

A. Assumptions

In order to design and implement the proposed testbed, the following assumptions have been considered to conduct the experiments successfully such as:

- IPv6 local network comprises of at least one gateway router, an ethernet switch, a new host, existing hosts and an attacker host.
- IPv6 address in the local network is obtained from SLAAC mechanism instead of using DHCPv6 server.
- The number of attacker hosts in an IPv6 local network are less than the number of legitimate hosts

Based on the assumptions the required hardware and software specifications for testbed setup environment are presented in Tables 1 and 2, respectively.

The hardware and software specifications have been selected based on the availability and support for IPv6 environment at NAv6 research institute to conduct the experiment successfully.

TABLE I. Details on Hardware Required for the Experiments

Hardware		**Details**
Computer Hardware	CPU	Intel® Core™ i7 3770 / 3.40GHz
	Memory	8 GB Ram
	Motherboard	IntelQ77 Express Chipset
	Network Interface Card	Intel® 82579LM Gigabit1 Ethernet LAN 10/100/1000
Other Network Devices	Network Patch cables	Digitus UTP Cat5e
	Switch	Cisco Catalyst 2960 Fast Ethernet
	Gateway Router	Cisco Router C7200

TABLE II. DETAILS ON SOFTWARE REQUIRED FOR THE EXPERIMENTS

Operating System		Role	Tools
Microsoft Windows	Windows 7 Ultimate 64-bit	Monitoring/ Victim Host	Wireshark
	Windows Vista Home Premium 64-bit	Victim Host	-
Linux Distributions	Ubuntu 14.04 LTS-desktop-amd64	Victim Host	-
	Fedora 3.17.4.x86_64	Victim Host	-
	Kali Linux 3.18.0-amd64	Attacker PC	THC IPv6 Attack Toolkit 2.7

Testbed setup environment comprises hosts (Host A, Host B, Host C and Host D) based on Windows as well as Linux Operating Systems so that to run the experiment on both the platforms in order to analyses the impact of DoS-on-DAD attack as the design and implementation of IPv6 stack in these Operating Systems differ slightly in some manners [13].

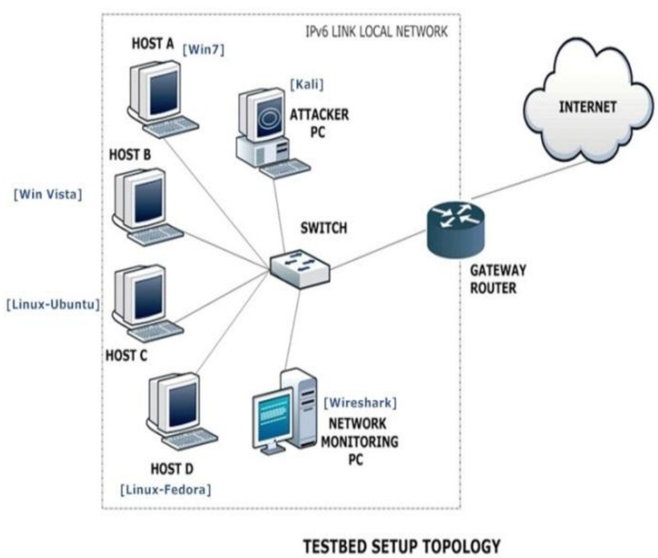


Fig. 5. Testbed setup environment

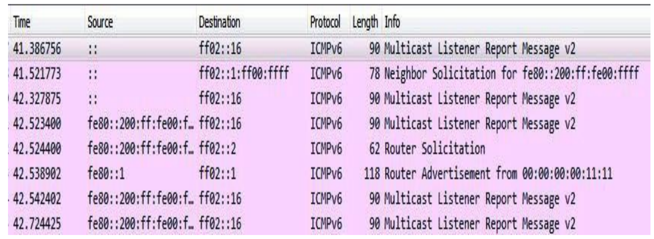
The Hackers Choice (THC) attacking toolkit [14] provides a set of tools that can enable the user to explore weaknesses in existing IPv6 implementations. One of the tools, called dos-new-ip6, can be used to run the DoS attack on DAD process in IPv6 local link network. Kali is a Linux-based open source system; it has built-in THC-IPv6 attacking toolkit support. Therefore, Kali have been used as an Attacker PC to exploit the testbed setup environment.

In order to monitor and capture the network traffic Wireshark [15, 16] network analyser tool has been used to analyse the captured network traffic. Cisco router C7200 has been used as a gateway router for the network and Cisco catalyst 2960 fast ethernet switch has been used to connect all the hosts in IPv6 link local network. Figure 5 depicts the testbed setup environment.

A. Senario Based testbed Setup

Based on the deployed IPv6 testbed setup environment, two experimental scenarios have been conducted such as: Normal Scenario and Attacking Scenario.

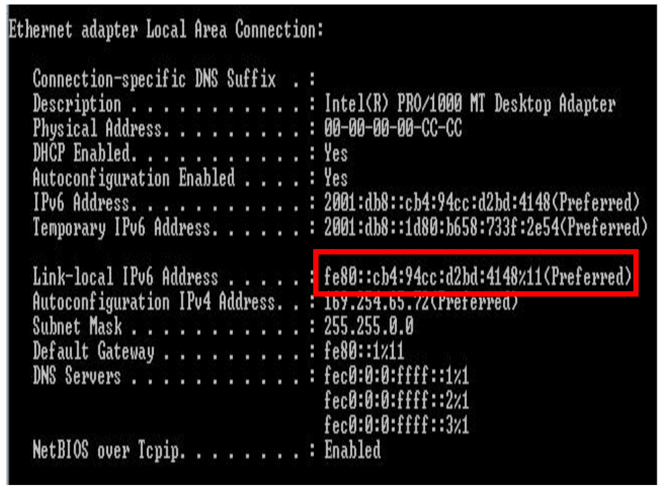
- Normal Scenario: In case of normal scenario, a default DAD process during address autoconfiguration in IPv6 link local communication has been analysed by capturing the ICMPv6 message types like RS, RA, NS and NA in Wireshark network analyzer tool as shown in Figure 6.



Time	Source	Destination	Protocol	Length	Info
41.386756	::	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
41.521773	::	ff02::1:ff00:ffff	ICMPv6	78	Neighbor Solicitation for fe80::200:ff:fe00:ffff
42.327875	::	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
42.523400	fe80::200:ff:fe00:f…	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
42.524400	fe80::200:ff:fe00:f…	ff02::2	ICMPv6	62	Router Solicitation
42.538902	fe80::1	ff02::1	ICMPv6	118	Router Advertisement from 00:00:00:00:11:11
42.542402	fe80::200:ff:fe00:f…	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
42.724425	fe80::200:ff:fe00:f…	ff02::16	ICMPv6	90	Multicast Listener Report Message v2

Fig. 6. ICMPv6 packets traffic analyses

In order to investigate the DAD process on various platforms, address autoconfiguration process has been performed on hosts with different Operating Systems such as Windows (Win7, Win Vista) and Linux (Ubuntu, Fedora) on a deployed IPv6 Testbed setup. After successful DAD process hosts are able to configure their preferred IPv6 link local addresses. Figure 7 depicts the Windows host after configuring its IPv6 link local address.



```
Ethernet adapter Local Area Connection:

   Connection-specific DNS Suffix  . :
   Description . . . . . . . . . . . : Intel(R) PRO/1000 MT Desktop Adapter
   Physical Address. . . . . . . . . : 00-00-00-00-CC-CC
   DHCP Enabled. . . . . . . . . . . : Yes
   Autoconfiguration Enabled . . . . : Yes
   IPv6 Address. . . . . . . . . . . : 2001:db8::cb4:94cc:d2bd:4148(Preferred)
   Temporary IPv6 Address. . . . . . : 2001:db8::1d80:b658:733f:2e54(Preferred)

   Link-local IPv6 Address . . . . . : fe80::cb4:94cc:d2bd:4148%11(Preferred)
   Autoconfiguration IPv4 Address. . : 169.254.65.72(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.0.0
   Default Gateway . . . . . . . . . : fe80::1%11
   DNS Servers . . . . . . . . . . . : fec0:0:0:ffff::1%1
                                       fec0:0:0:ffff::2%1
                                       fec0:0:0:ffff::3%1
   NetBIOS over Tcpip. . . . . . . . : Enabled
```

Fig. 7. Snapshot of Window's host IPv6 address autoconfiguration.

Likewise, Figure 8 shows that Linux based host after successful DAD process configured its link local address in IPv6 network.

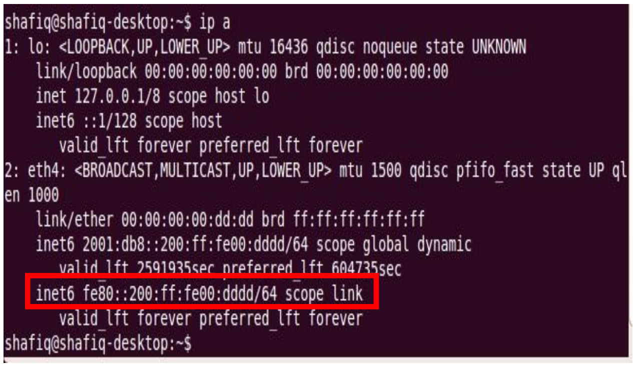


Fig. 8. Snapshot of Linux host Address Autoconfiguration

- Attacking Scenario: In attacking scenario, an attempt of DoS-on-DAD attack during address autoconfiguration in IPv6 link local communication has been examined by capturing the ICMPv6 message types like RS, RA, NS and NA in Wireshark network analyser tool as shown in Figure 9.

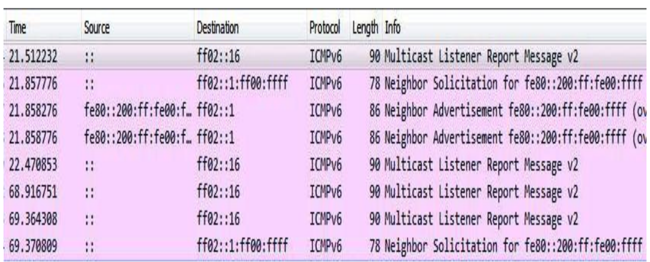
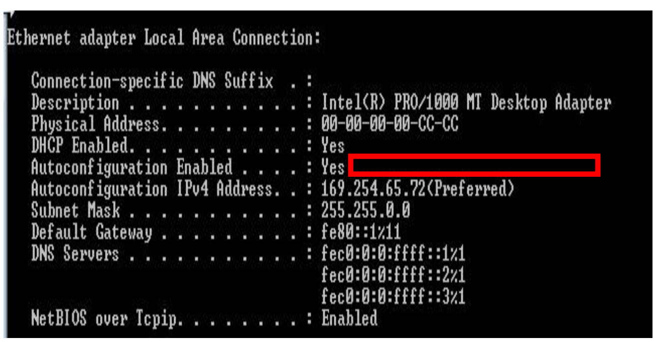


Fig. 9. Screenshot of DoS-on-DAD attack.

In order to test the scenario, Kali as an attacker (PC) have been used to run the DoS on DAD attack with the help of THC-IPv6 attacking toolkit during address autoconfiguration process in IPv6 link local network. During the attack, it has been noticed that Windows-based hosts, that is, Host A and Host B are unable to configure IPv6 link local addresses as depicted in Figure 10.



While ongoing DoS attack, IPv6 hosts cannot obtain the IP addresses as the attacker PC claims that all the IP addresses are already being obtained by it during the attempts of DAD process in IPv6 link local network as shown in Figure 13.

Fig. 10. Host unable to configure IPv6 link local address

Likewise, Linux Hosts such as; Host C and Host D are able to generate tentative IP address but fails to perform DAD process. Thus, due to the DAD process failure hosts are unable to verify the uniqueness of the generated (tentative) IP address. Since, only the preferred IP address after successful DAD process can allow host(s) to communicate with other neighboring hosts within the same link. Therefore, new host(s) cannot communicate with existing hosts in the IPv6 link local network as shown in Figure 11.

Fig. 11. Snapshot of DAD process failure

V. Testbed Outcome

In this study, dos-new-ip6 attacking tool was used to examine the impact of DoS attack during DAD process on Windows and Linux based hosts on deployed IPv6 testbed setup environment as depicted in Figure 12.

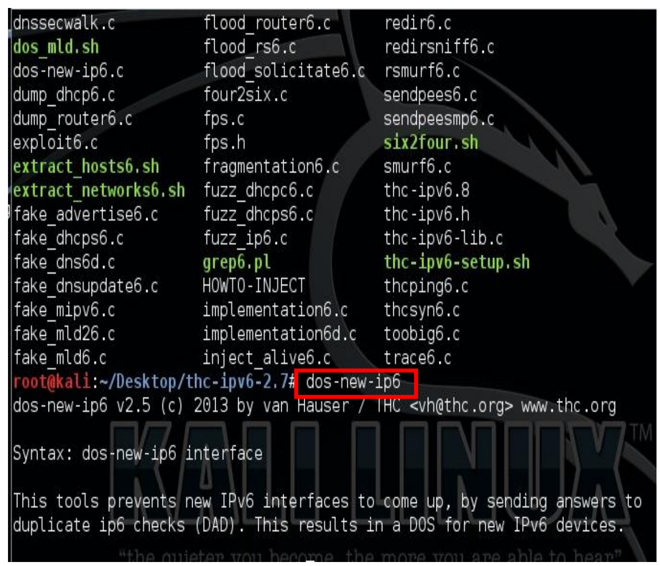


Fig. 12. Snapshot of attacker attempting DoS-on-DAD attack

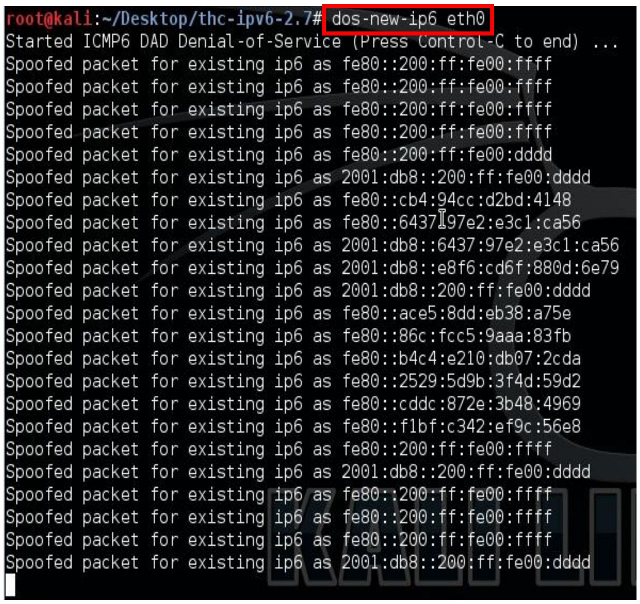


Fig. 13. Snapshot of DoS-on-DAD attack

Since, the attacker disrupts the IPv6 hosts to obtain preferred IP addresses by causing DAD process failure. As a result, the new hosts are unable to communicate with their neighboring hosts on the same link. Figure 14 and 15 depicts the outcome of the experiment conducted on both Windows and Linux OS platforms respectively.

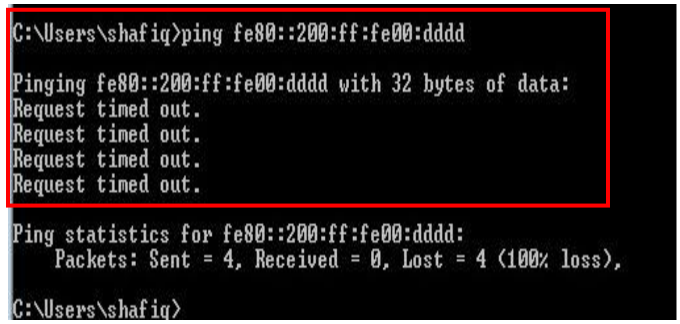


Fig. 14. Snapshot of Window's host communication disruption.

Fig. 15. Snapshot of Linux host communication disruption.

VI. CONCLUSION AND FUTURE WORK

The purpose of this paper was to analyse the impact of DoS on DAD attack and its outcome. In pursuant to this, an IPv6 testbed has been designed and implemented to carry out the attacks on multiple OS platforms. The testbed outcome has shown that during DoS-on-DAD attack IPv6 hosts are unable to obtain IPv6 addresses due to DAD process failure. There are existing mechanisms and approaches that, to some length, address this issue but have drawbacks in terms of efficiency and complexity. Thus, a more effective security mechanism is required to secure DAD process during address autoconfiguration in IPv6 link local network.

Therefore, our future work will be to propose a security mechanism which ensures a secure DAD process during address autoconfiguration in IPv6 link local communication by preventing denial of service (DoS) attack with reduced overhead.

ACKNOWLEDGMENT

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REFERENCES

[1] K. Batiha, K. Batiha, and A. AbuAli, THE NEED FOR IPv6, International Journal of Academic Research, vol. 3(3), 2011.

[2] E. Durdaugi and A. Buldu, IPV4/IPV6 security and threat comparisons, Procedia-Social and Behavioral Sciences, vol. 2(2): pp. 5285–5291, 2010.

[3] AlSa'deh, H. Rafiee, and C. Meinel, IPv6 stateless address autoconfiguration: balancing between security, privacy and usability, in Foundations and Practice of Security, Springer, pp. 149–161, 2012.

[4] H. Rafiee and C. Meinel, Privacy and security in IPv6 networks: challenges and possible solutions, in Proceedings of the 6th International Conference on Security of Information and Networks, pp. 218–224, 2013.

[5] J. Ullrich, K. Krombholz, H. Hobel, A. Dabrowski, and E. Weippl, IPv6 security: attacks and countermeasures in a nutshell, in Proceedings of the 8th USENIX conference on Offensive Technologies, pp. 5–5, 2014.

[6] S. U. Rehman and S. Manickam, Significance of Duplicate Address Detection Mechanism in Ipv6 and its Security Issues: A Survey, Indian Journal of Science and Technology, vol. 8(30), 2015.

[7] L. Prudente, E. Aguirre, A. F. M. Hdez, and R. J. Garcia, DoS Attacks Flood Techniques, International Journal of Combinatorial Optimization Problems and Informatics, vol. 3(2): pp. 3–13, 2012.

[8] S.T. Zargar, J. Joshi, , and D.Tipper: A survey of defense mechanisms against distributed denial of service (DDoS) flooding attacks, Communications Surveys & Tutorials, IEEE, 15 (4): pp. 2046-2069, 2013.

[9] S. Ahmed, R. Hassan, and N. E. Othman, Improving security for IPv6 neighbor discovery, 2015 International Conference on Electrical Engineering and Informatics (ICEEI), pp. 271–274, 2015.

[10] Conta, S. Deering, and M. Gupta, Internet Control Message Protocol (ICMPv6) for the Internet Protocol version 6 (IPv6), RFC 4443, March 2006.

[11] R.M.Saad, S. Ramadass, and S. Manickam, A study on detecting ICMPv6 flooding attack based on IDS. Australian Journal of Basic and Applied Sciences, vol.7: pp. 175-181, 2013.

[12] R.K.Murugesan, and S.Ramadass: REVIEW ON IPV6 SECURITY VULNERABILITY ISSUES AND MITIGATION METHODS, International Journal of Network Security & Its Applications, 4 (6), 2012.

[13] S. S. Mohamed, A. Y. M. Abusin, and D. Chieng, Evaluation of IPv6 and comparative study with different Operating Systems, Third International Conference on Information Technology and Applications, ICITA 2005, vol. 2: pp. 665–670, 2005.

[14] THC-IPv6 attack toolkit 2015-04-19. Available from: https://www.thc.org/thc-ipv6/.

[15] V. Ndatinya, Z. Xiao, V. R. Manepalli, K. Meng, and Y. Xiao, Network forensics analysis using Wireshark, International Journal of Security and Networks, vol. 10(2): pp. 91–106, 2015.

[16] Qadeer, Mohammed Abdul, Mohammad Zahid, Arshad Iqbal, and MisbahurRahman Siddiqui. Network traffic analysis and intrusion detection using packet sniffer. Second IEEE International Conference on Communication Software and Networks, (ICCSN'10). pp. 313-317, 2010

A Self-organizing Location and Mobility-Aware Route Optimization Protocol for Bluetooth Wireless

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***Abstract*—Bluetooth allows multi-hop ad-hoc networks that contain multiple interconnected piconets in a common area to form a scatternet. Routing is one of the technical issues in a scatternet because nodes can arrive and leave at arbitrary times; hence node mobility has a serious impact on network performance. Bluetooth network is built in an ad-hoc fashion, therefore, a fully connected network does not guarantee. Moreover, a partially connected network may not find the shortest route between source and destination. In this paper, a new Self-organizing Location and Mobility-aware Route Optimization (LMRO) protocol is proposed for Bluetooth scatternet, which is based on node mobility and location. The proposed protocol considered the shortest route ahead of the source and destination nodes through nodes location information. In addition, proposed protocol guarantees network connectivity through executing Self-organizing procedure for the damaged route by considering signal strength. The proposed LMRO protocol predicts node mobility through the signal strength and activates an alternate link before the main link breaks. Simulation results show that the LMRO protocol has reduced the average hop count by 20%-50% and increased network throughput by 30%-40% compared to existing protocols.**

Keywords—Bluetooth; Hop count; Mobility; Routing; Resource optimization; Scatternet; Self-healings

I. INTRODUCTION

In recent years, wireless technology has facilitated consumers in terms of conventional cable independence and has provided facilities to connect multiple devices for short-range connectivity [1]. Among various appliances of the wireless technology, Bluetooth is one of the most popular because of its low cost and low power applications [2]. Initially, Bluetooth was only launched as a wireless cable replacement but later it became an emerging wireless technology. According to Bluetooth specifications [3], devices can communicate through a basic network unit at called a piconet. A piconet consists of one master device and most seven active slave devices at the same time. Since Bluetooth allows synchronous transmission, all slaves are synchronized with the clock of the piconet master. The master controls the entire communication in a piconet; it allocates channel and schedules data transmission for its slaves. All the slaves listen to the master and reply to the master when the master explicitly addresses any slave. The master has a unique queue for each slave, while each slave maintains a queue of packets that have to be sent to the master. If there is no data for the slave, the master sends zero payload POLL packets to the slave, and in response, if the slave also has no data for the master; it sends a NULL packet to the master.

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Bluetooth devices connected with different master cannot directly communicate with each other even if their distance is shorter than the radio communication range [4]. The reason is that their channel hopping sequences are different [5]. However, two devices at different piconets are allowed to communicate through an overlapping device called a relay/bridge node. The relay/bridge node can be Slave-Slave (SS) or Master-Slave (MS) in its status. An SS relay device concurrently participates in more than one piconet, and alternatively plays the role of slave. An MS relay device plays a master role in one piconet and a slave role in other piconets [6]. A relay can be a slave in multiple piconets but it can act as master in only one piconet because if multiple piconets have the same master, their frequency hopping would be the same and cause interference. Therefore, a relay provides multi-hop communication among different piconets, and it shares its time among different piconets through the Time Division Multiplexing technique. When different piconet devices intend to communicate, they form a scatternet, which is a bigger network based on multiple piconets being connected through a relay; this is called a scatternet. Communication in a scatternet is possible through a master and relay, where a master uses the services of a relay to forward packets from one piconet to another [7]. Bluetooth specifications however, do not define a protocol for inter-piconet communication; it is achieved through higher layers that significantly affect the network performance.

Bluetooth implements centralized control, where normal ad-hoc network protocols cannot be used for inter-piconet communication [8-14]. Bluetooth specifications do not provide any solution for inter-piconet communication, therefore, different protocols exist in literature. In this context, most of the research is focused on reducing the intermediate hop count that could improve the system performance. Few research contributions in the area of Bluetooth inter-piconet communication are highlighted in [15-18]. The type of scatternet topology has a significant impact on network performance [19]. The inter-piconet communication in a scatternet is still an open research issue, as it is not defined in Bluetooth [20]. Bluetooth's link formation time is too long;

therefore dynamic source routing is preferred for scatternet communication. Furthermore, location-aware protocols have been proposed using different technologies; however, these technologies cannot measure node location [21, 22] accurately. In [23], the authors proposed "Indoor positioning in Bluetooth networks using fingerprinting and lateration approach (IPFT)". IPFT has significantly reduced error between node estimation and actual position, where node information is transmitted without user participation.

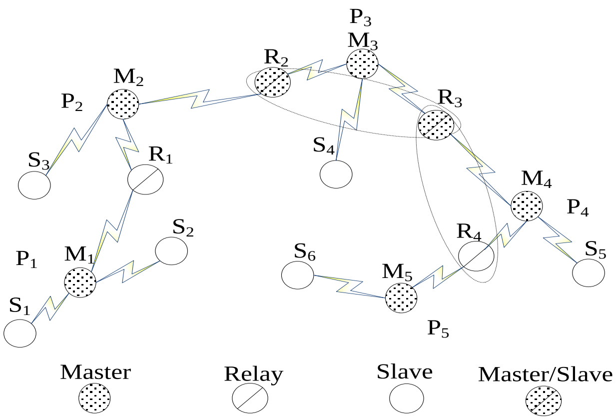
The rest of the paper is organized as follows. Literature review is done in Section 2. To create the shortest path using the IPFT, Self-organizing Location and Mobility-aware Route Optimization is proposed in Section 3. Simulation results containing the performance analysis of the proposed routing protocol and its comparison with similar routing protocols are presented in Section 4 by using the NS-2 and UCBT. Finally, Section 5 concludes the whole paper along with some possible future work.

II. Background and Related Works

Bluetooth specifications do not provide any solution for inter-piconet scheduling, i.e. scatternet communication. Therefore, different approaches are in practice for inter-piconet communication based on the six feasible scatternet topologies as elaborated in [24]. All these configurations have their own benefits and drawbacks. A complex management algorithm is required for mesh topologies but their strength is that if a link fails, communication is still possible [25, 26]. Ring and tree configurations are easy for routing but result in inefficient utilization of bandwidth. Literature review reveals that several routing protocols have been proposed to construct an efficient route in a scatternet. Based on this observation, the development of a routing protocol in a scatternet of a Bluetooth network shall consider. Relay Reduction and Disjoint Routes Construction (RRDR) [27], Location Aware Routing Protocol (LARP) [28], and Scatternet Formation Algorithm for Bluetooth Networks (SFBN) [29] as the reference models since these protocols have significant similarities with the proposed routing protocol. As RRDR does not demand for location information, while LARP and SFBN are based on location information to reduce number of hops for inter-piconet communication.

A. *Relay Reduction and disjoint route construction protocol (RRDR)*

RRDR [27] was proposed to reduce unnecessary relays and reduce route length. RRDR performs relay reduction and disjoint route construction for a scatternet over a Bluetooth radio system in a distributed manner. RRDR reduces the hop count between a source and its destination, based on relay. An example of RRDR route reduction is shown in Fig. 1, where the source node S_3 broadcasts a route RSP packet to the destination S_6 node, ($S_3 \rightarrow M_2 \rightarrow R_2 \rightarrow M_3 \rightarrow R_3 \rightarrow M_4 \rightarrow R_4 \rightarrow M_5 \rightarrow S_6$). When S_6 receives the RSP, it appends its BD_Addr and k_{offset} value between S_6 and M_5 and transmits the RRP packet to M_4. All the intermediate devices perform the same operation as S_6. Finally, S_3 receives the BD_Addr and k_{offset} information of all the devices from source to destination. For reducing the intermediate hops, S_3 start paging procedure and tries to construct the shortest path, but there is no node available, therefore, it simply forwards the packet. On receiving the packet R_2 also tries to reduce the route as R_2 is in its range, so it creates a new connection with R_3 and acts as a master in the new piconet. Thus, RRDR constructs a final route between S_1 and S_5, which is ($S_2 \rightarrow M_2 \rightarrow R_2 \rightarrow R_3 \rightarrow R_4 \rightarrow M_5 \rightarrow S_6$). It can be observed that RRDR needs 6 hops to create a route from the source to the destination. In this scenario, RRDR has not completely optimized the route length because it only considers relay and master nodes for route length optimization.



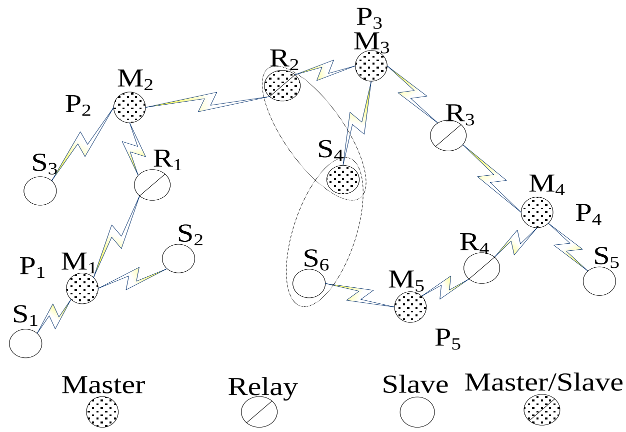
RRDR ($S_3 \rightarrow M_2 \rightarrow R_2 \rightarrow R_3 \rightarrow R_4 \rightarrow M_5 \rightarrow S_6$)

Fig. 1. Route construction through RRDR

B. *Location Aware Routing Protocol (LARP)*

LARP [28] was proposed for a Bluetooth scatternet, which also considers slave nodes for hop count reduction between source and destination. A source node appends its ID and location (LOC) and transmits a RSP to a master node, the RSP contains the destination ID, but the LOC field is empty as it is unknown. On receiving the RSP, each master node performs route reduction and appends its ID and LOC, and forwards the RSP to all the connected relay nodes. On receiving the RSP, each relay node appends its ID and LOC, and forwards to the connected masters. Finally, destination node receives RRP and replies RRP in reverse order to the master. Since each master knows its slaves ID and location, a master node checks for hop count reduction and replaces the intermediate hops with any node that can reduce the hop counts. This process is continued until the RRP does not reach the source node. Thus, the source node gets the shortest path to the destination node, and it starts the route construction process.

As an example, S_3 forwards a RSP for S_6 through ($S_3 \rightarrow M_2 \rightarrow R_2 \rightarrow M_3 \rightarrow R_3 \rightarrow M_4 \rightarrow R_4 \rightarrow M_5 \rightarrow S_6$). After applying all the route reduction procedures, according to LARP, the source node gets the RRP, which contains the final shortest path ($S_3 \rightarrow M_2 \rightarrow R_2 \rightarrow S_4 \rightarrow S_6$). In the route construction phase, R_2 goes to the Page state where it acts as the master, and S_4 goes to the Page Scan state to become a slave; thus, both the devices build a new connection. The same procedure is followed by S_4 and S_6, where LARP reduces the hop counts to four, as shown in Fig. 2. Although, LARP considers slave nodes for hop count reduction, it depends heavily on RSP, and therefore, it is analyzed that LARP has not completely reduced the route length.



LARP ($S_3 \rightarrow M_2 \rightarrow R_2 \rightarrow S_4 \rightarrow S_6$)

Fig. 2. Route construction through LARP

C. Scatternet Formation Algorithm for Bluetooth Networks (SFBN)

The authors in SFBN [29] used efficient location-based routing protocol for Bluetooth scatternet. In SFBN when a node receives RSP, if destination address matches its Bluetooth Device Address (BD_Add), it sends packet to upper layer, otherwise the received packet is forwarded to next MS bridge. On receiving RSP, MS finds destination information, if it is in its routing table it forwards the packet to downstream. Otherwise, the packet is forwarded to SS bridge for upstream master. This process continues until packet is received by the destination. A source node S3 sends a RSP to the destination node S6. Since SFBN constructs the route through a relay and a master, the RSP is forwarded through (*S3 → M2 → R2 → M3 → R3 → M4 → R4 → M5 → S6*), which is the final routing path between S3 and S6. SFBN route mainly based on scatternet formation, in the above example it follows (*S3 → M2 → R2 → S4 → S6*).

D. Hybrid indoor position estimation technique

Bluetooth device can obtain location information via GPS [30], or advanced antenna techniques [31]. But these techniques are not suitable for indoor environments due to accuracy limitation. A Hybrid Indoor Position Estimation [32] technique is proposed to find node location in Bluetooth network. In this technique, inquiry-based Received Signal Strength Indicator (RSSI) is obtained and passed to Kalman filter to estimate position of the target node. A mobile node position is estimated through RSSI and filtered by Gradient predictor and filter. The estimated position is denoted by Target(x; y). In the offline stage of fingerprinting-based approach, the whole area is divided into equal size grids. The RSSI samples are collected at each grid several times. The average of measured RSSI values is calculated and stored in a lookup of table with their corresponding coordinates. The RSS measurements are observed and the mean RSSI value for each location is calculated and stored in a database. Euclidian distance formula is used to calculate the distance between these points. When the distances are given, then trilateration approach can be used to calculate the coordinates of the target location.

Based on a review of these analyses, it is observed that every new protocol has tried to reduce the hop count, but none of them has completely succeeded in the scatternet. It has been analyzed that RRDR follows the longest route, while SFBN and LARP have reduced the route length. Moreover, LARP obtains node location through Bluetooth Location Network (BLN) [31] that can support only static environment. The main drawback with all these techniques is that they do not consider the case when a device suddenly goes out from the radio range. Once a link breaks between a connected source and destination, new connection procedure is starts from inquiry and inquiry scan that it will take more time to find another way for connecting the broken links. It is analyzed due to node mobility routing path may be disturbed and increasing the routing overheads.

The proposed LMRO contains two basic procedures for route optimization. First, the final piconet master tries to find the shortest route ahead of destination host piconet. Second, on receiving an RRP, the source host master tries to reduce intermediate hosts based on destination location. In addition, the proposed protocol repaired the damaged routing path by considering the location information and mobility of the nodes, if routing path is disturbed due to nodes mobility in existing scatternet. Thus, proposed protocol overcomes frequent link disconnection setback.

III. The Proposed Self-Organizing Location and Mobility-Aware Route Optimization Protocol

In this section, the LMRO protocol is proposed for a Bluetooth scatternet. The proposed LMRO requires the location information of mobile nodes to reduce route length between a source and destination in the scatternet topology. In addition, a role-switching operation is performed to dynamically construct a link during the route construction and repairing procedure. In the proposed LMRO each master maintains a node information table, where node location, BD_Addr, and k_{offset} are stored. LMRO finds the node location through IPFT technique and not only constructs the shortest routing path between source and destination but also guarantees network connectivity.

A. The proposed LMRO system model

Assume a Bluetooth scatternet is constructed. There are N numbers of randomly distributed nodes, where each node $i \in N = \{1, 2, \dots, N\}$ is selected to be either a slave, relay, or master in the scatternet. A Bluetooth node has a unique 48-bit BD_Addr, which is used for synchronization. The set of master is denoted by M, set of slaves is denoted by S, and set of relays is denoted by R such that $M \cup S \cup R = N$. A piconet is defined as follows:

Piconet:

$$P_i\left(S_{ij} \in M_i\right) = \begin{cases} 1 & S_{ij}\ \text{connects}\ M_i \\ 0 & S_{ij}\ \text{does not connect}\ M_i \end{cases} \tag{1}$$

$$\text{Subject to} \quad S_{ij} \leq 7, \forall i \tag{2}$$

$$\text{Distance} \quad ED\left(S_{ij} \wedge M_i\right) < 10m \tag{3}$$

where P_i represents the i^{th} piconet and M_i corresponds to the piconet master, S_{ij} is the j^{th} slave node in i^{th} piconet. S_{ij} is set to

1 if there is a master-slave relationship between node *i* and node *j*, otherwise it is set to 0. Constraint (2) determines each piconet has one master and a maximum of up to seven active slaves, where constraint (3) limits each slave within the range of 10 m from the master. Coordinates (x, y) of a mobile node are obtained using IPFT technique in a scatternet topology over a 2-D plane without user participation. The distance between two points (devices) is calculated through equation 4.

$$ED = \sqrt{\left(x_1 - x_2\right)^2 - \left(y_1 - y_2\right)^2} \quad (4)$$

where *ED* denotes Euclidian distance, and (x, y) are the coordinates of i^{th} and j^{th} node in scatternet respectively.

In the proposed protocol, each master maintains a Node Information Table (*NIT*), $S_{ij} \in M_i = NIT \sum_{j=1}^{k}(ID, NCLK, LOC)$, which contains the node's *ID*, k_{offset}, and *LOC*, where k is total number of devices connected with i^{th} master.

$$Src_{HM} = Src\left(S_{ij}\right) \in P_i \quad (5)$$

where Src_{HM} denotes source host master and S_{ij} is one of the connected slaves with the master.

A master device is called source host master (Src_{HM}) if the route request is initiated one of its connected slave. A master is called Destination host master (Dst_{HM}), if the destination belongs the same piconet mentioned in equation (6). A Src_{HM} and Dst_{HM} unicast route search packet and route reply packet respectively to optimize route length. A potential candidate (node) in the network is called Auxiliary host (AH), if it can reduce the route length. The Src_{HM} and Dst_{HM} nodes find *ED* between each node in RSP and RRP respectively in the NIT, and if any nearest relay is found by the source or destination, it forwards the packet to find the shortest route.

$$Dst_{HM} = Dst\left(S_{ij}\right) \in P_i \quad (6)$$

In the proposed protocol, each master also gets to know the location information of the intermediate nodes between a source and destination through IPFT. According to Bluetooth, master and slave have periodic communication. In the proposed protocol each master obtains nodes information through RSSI and it takes a constant *O*(1) time. The proposed route optimization protocol consists of three main steps (Route search, Route reply, Route construction). In addition, mobility of mobile node is also monitored during transmission phase through RSSI.

B. Route optimization procedure

This sub-section describes the proposed route optimization procedure that is divided into three phases: route search, route reply, and route construction. The proposed LMRO constructs the shortest routing path by using the ID, k_{offset}, and location information of the nodes.

1) Route Search Phase

Before starting an inter-piconet communication, each source initiates a route request. When a source initiates a route request and transmits a RSP to the Src_{HM} node in order to find a route to the destination that exists in a different piconet. The RSP payload is used to store the nodes' information as shown in Fig. 4. Initially, the RSP contains the source ID and LOC, while it is assumed that the source knows the destination node ID, however the location is unknown. On receiving the RSP, the Src_{HM} appends its ID and LOC and forwards the packet to all the attached relays. On receiving the RSP, the relay also includes its ID and LOC, and forwards the RSP to all connected masters. All the receiving masters then search for any node that can reduce hop count, and append its information in the RSP. If the next selected host is a relay, the master will not include its information; it simply forwards the RSP, and removes the unnecessary nodes' information from the RSP, since the relay itself includes the required information in the RSP. Ultimately, several RSPs are received by the destination, but it only considers the least number of hops. The destination appends required information in the RSP and forwards to Dst_{HM}. Where Dst_{HM} searches for an Auxiliary Host, if Dst_{HM} finds any AH, it forwards the RSP to the AH, and all the intermediate nodes include their information in the RSP. The final AH master performs route optimization and returns the RSP to Dst_{HM}.

The RSP format is shown in Fig. 3. Source S_3 initiated a route request and transmitted a RSP to destination S_6, where next hop and Auxiliary host field are NULL. The RSP is forwarded through ($S_3 \rightarrow M_2 \rightarrow R_2 \rightarrow M_3 \rightarrow R_3 \rightarrow M_4 \rightarrow R_4 \rightarrow M_5 \rightarrow S_6$). Initially, S_3 added its ID and LOC in the RSP and forwarded the RSP to M_2, where M_2 became the Src_{HM}, and appended its ID and LOC information in the next hop field and forwarded the received packet to R_2. As R_2 was a relay it simply appended its information and forwarded to M_3, where M_3 performed route optimization and did not include its information in the RSP. As the next hop R_3 is in the range of R_2 and it has reduced the roué length. Finally, S_6 received RSP with optimized route ($M_2 \rightarrow R_2 \rightarrow R_3 \rightarrow R_4 \rightarrow M_5$) information. It has been observed, that in end of route search the route length is 6 hops which is the same path as RRDR.

Route Search Packet (RSP)				
Sender	**Source**	**Next Hop**	**Destination**	**AH**
S_3	$S_{3(ID,LOC)}$	NULL	$S_{6(ID, NULL)}$	NULL
M_2	$S_{3(ID,LOC)}$	$M_{2(ID, LOC)}$	$S_{6(ID, NULL)}$	NULL
R_2	$S_{3(ID,LOC)}$	$M_{2(ID, LOC)} \rightarrow R_{2(ID, LOC)}$	$S_{6(ID, NULL)}$	NULL
M_3	$S_{3(ID,LOC)}$	$M_{2(ID, LOC)} \rightarrow R_{2(ID, LOC)}$	$S_{6(ID, NULL)}$	NULL
R_3	$S_{3(ID,LOC)}$	$M_{2(ID, LOC)} \rightarrow R_{2(ID, LOC)} \rightarrow R_{3(ID, LOC)}$	$S_{6(ID, NULL)}$	NULL
M_4	$S_{3(ID,LOC)}$	$M_{2(ID, LOC)} \rightarrow R_{3(ID, LOC)} \rightarrow R_{3(ID, LOC)}$	$S_{6(ID, NULL)}$	NULL
R_4	$S_{3(ID,LOC)}$	$M_{2(ID, LOC)} \rightarrow R_{2(ID, LOC)} \rightarrow R_{3(ID, LOC)} \rightarrow R_{4(ID, LOC)}$	$S_{6(ID, NULL)}$	NULL
M_5	$S_{3(ID,LOC)}$	$M_{2(ID, LOC)} \rightarrow R_{2(ID, LOC)} \rightarrow R_{3(ID, LOC)} \rightarrow R_{4(ID, LOC)} \rightarrow$	$S_{6(ID, NULL)}$	NULL

		$M_{5(ID, LOC)}$		
S_6	$S_{3(ID,LOC)}$	$M_{2(ID, LOC)} \rightarrow R_{2(ID, LOC)} \rightarrow R_{3(ID, LOC)} \rightarrow R_{4(ID, LOC)} \rightarrow M_{5(ID, LOC)}$	$S_{6(ID, LOC, k_{offset})}$	NULL

Fig. 3. Route search packet through different nodes in the scatternet

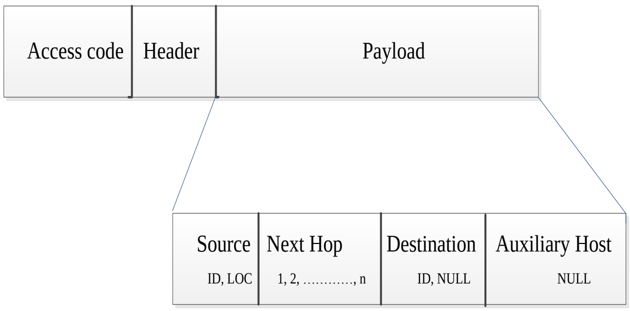


Fig. 4. Route Search Packet format

2) Route Reply Phase

Once route search process finished, the destination sends a unicast reply to the source host. During the route reply, the destination acts as a source and sends a RRP along the selected shortest path, that is created during the route search phase. It is important to note that RRP is sent in the reverse order of RSP. Each master knows the location and BD_Addr of its slaves. When a master receives the RRP, it again performs route optimization based on updated nodes information. If any of its slave is selected to reduce hop count for the new route. The master appends the selected node information, i.e. ID, LOC and Native Bluetooth k_{offset} and forwards the RRP to the next hop. Ultimately, the RRP is received by Src_{HM}, if the Src_{HM} finds any AH it forwards the RRP to AH and waits for reply. All the intermediate nodes append their information in the RRP, until it is received by the AH master. On receiving the RRP AH master verifies if any node can reduce the hop count. The AH master forwards the received RRP to AH, where selected AH appends required information in the RRP, and sends a unicast RRP to the source. In the next step, AH enters into page scan mode to create a new connection.

Using the example of Fig. 1. the RRP format is given in Fig. 5. Route optimization through RRP is explained, where S_3 forwards the RSP through ($S_3 \rightarrow M_2 \rightarrow R_2 \rightarrow M_3 \rightarrow R_3 \rightarrow M_4 \rightarrow R_4 \rightarrow M_5 \rightarrow S_6$) to S_6. All intermediate masters run the optimization algorithm, but only M_3 found a node (S_4) that replaced (R_3, R_4, M_5) and reduced 2 hops. Finally, Src_{HM} M_2 received the RRP, it checked in NIT for AH, and forwarded the RRP to AH R_1. On receiving RRP R_1 added required information in AH field and forwarded RRP to M_1. It can be observed that the distance can be reduced through S_2, therefore, M_1 forwarded RRP to S_2. On receiving the RRP, S_2 appended its BD_Addr and k_{offset} value between S_2 and M_1 and transmits the RRP packet back to M_1. Finally, S_3 received the RRP, where (M_2 , R_2, S_4) *are replaced with* S_2. Thus, numbers of intermediate host are decreased to one, which is the best shortest path in the present scatternet.

Route Reply Packet (RRP)				
Sender	**Source**	**Next Hop**	**Destination**	**AH**
S_6	$S_{3(ID,LOC)}$	$M_{2(ID, LOC)} \rightarrow R_{2(ID, LOC)} \rightarrow R_{3(ID, LOC)} \rightarrow R_{4(ID, LOC)} \rightarrow M_{5(ID, LOC)}$	$S_{6(ID, Loc, k_{offset})}$	NULL
M_5	$S_{3(ID,LOC)}$	$M_{2(ID, LOC)} \rightarrow R_{2(ID, LOC)} \rightarrow R_{3(ID, LOC)} \rightarrow R_{4(ID, LOC)} \rightarrow M_{5\ (ID, LOC, k_{offset})}$	$S_{6(ID, Loc, k_{offset})}$	NULL
R_4	$S_{3(ID,LOC)}$	$M_{2(ID, LOC)} \rightarrow R_{2(ID, LOC)} \rightarrow R_{3(ID, LOC)} \rightarrow R_{4(ID, LOC, k_{offset})} \rightarrow M_{5(ID, LOC, k_{offset})}$	$S_{6(ID, Loc, k_{offset})}$	NULL
M_4	$S_{3(ID,LOC)}$	$M_{2(ID, LOC)} \rightarrow R_{2(ID, LOC)} \rightarrow R_{3(ID, LOC)} \rightarrow R_{4(ID, LOC, k_{offset})} \rightarrow M_{5(ID, LOC, k_{offset})}$	$S_{6(ID, Loc, k_{offset})}$	NULL
R_3	$S_{3(ID,LOC)}$	$M_{2(ID, LOC)} \rightarrow R_{2(ID, LOC)} \rightarrow R_{3(ID, LOC, k_{offset})} \rightarrow R_{4(ID, LOC, k_{offset})} \rightarrow M_{5(ID, LOC, k_{offset})}$	$S_{6(ID, Loc, k_{offset})}$	NULL
M_3	$S_{3(ID,LOC)}$	$M_{2(ID, LOC)} \rightarrow R_{2(ID, LOC)} \rightarrow S_{4(ID, LOC, k_{offset})}$	$S_{6(ID, Loc, k_{offset})}$	NULL
R_2	$S_{3(ID,LOC)}$	$M_{2(ID, LOC)} \rightarrow R_{2(ID, LOC, k_{offset})} \rightarrow S_{4(ID, LOC,)}$	$S_{6(ID, Loc, k_{offset})}$	NULL
M_2	$S_{3(ID,LOC)}$	$M_{2(ID, LOC, k_{offset})} \rightarrow R_{2(ID, LOC, k_{offset})} \rightarrow S_{4(ID, LOC, k_{offset})}$	$S_{6(ID, Loc, k_{offset})}$	$R_{1(ID, LOC)}$
R_1	$S_{3(ID,LOC)}$	$M_{2(ID, LOC, k_{offset})} \rightarrow R_{2(ID, LOC, k_{offset})} \rightarrow S_{4(ID, LOC, k_{offset})}$	$S_{6(ID, Loc, k_{offset})}$	$R_{1(ID, LOC, k_{offset})}$
M_1	$S_{3(ID,LOC)}$	$S_{2(ID, LOC)}$	$S_{6(ID, Loc, k_{offset})}$	NULL
S_2	$S_{3(ID,LOC)}$	$S_{2(ID, LOC, k_{offset})}$	$S_{6(ID, Loc, k_{offset})}$	NULL

Fig. 5. Format of RRP through different nodes in the scatternet

3) Route Construction Phase

Finally, the route construction phase is executed after the completion of the route search and route reply phases. Ultimately, the source receives all the possible intermediate nodes information that can be used to construct the shortest path between a source and a destination. The source checks the next hop if it is not Src_{HM}, it goes to the Page mode and tries to connect the next hop. There are 32 page frequencies with 1.28s interval. Frequencies are divided into two trains (train A and train B) mentioned in equation 7 and 8.

$$A-train\{f(k-8)...f(k)...f(k+7)\} \tag{7}$$

$$B-train\{f(k+8)...f(k+15), f(k-16),..., f(k-9)\} \tag{8}$$

where f(k) is receiver frequency of paged device, the key k indicates the input functions.

If the sequence selection is set to page state then the paging device use the $A-train\{f(k-8)...f(k)...f(k+7)\}$. There exist 32 paging frequencies including a page hopping sequence which is obtained by the BD_Addr of the paged device. Bluetooth devices change their listening frequencies after 1.28s [33]. The master page response Xprm hopping sequence can be gained by the equation 9 for X input:

$$X_{prm} = [CLKE^*_{16-12+koffset^*} + (CLKE^*_{4-2,0} - CLKE^*_{16-12}) \bmod 16 + N] \bmod 32 \tag{9}$$

The master device freezes its predictable slave clock to the value that triggered a reply from the paged device. It is equal to using the clock values estimation when receiving the slave response. The frozen clock value is used at the content where the recipient's access code is identified. Let N be a counter that starts from zero and increases by one for each time when CLKN is set zero that matches to the start of a master TX slot. Once the connection is established, it forwards the selected route packet to the next hop. The route construction process continues until the packet does not reach the destination. Once the connection is established, both the nodes start transmission, and when transmission, all nodes return to the original state, and re-apply the role-switching operation.

Consider an example of first route from (S_3 to S_6). Once S_2 replied it entered into the HOLD (low power) mode in P_1, and started the Page-Scan procedure to construct a new piconet to reduce the hop count. Finally, S_3 received the BD_Addr and k_{offset} information of all the devices from source to destination. For reducing the intermediate hops, S_3 entered into the HOLD mode in P_2 and tried to construct the shortest path, i.e. ($S_{3\,(ID,\,LOC)} \rightarrow S_{2\,(ID,\,LOC,\,k_{offset})} \rightarrow S_{6(D,\,LOC,\,k_{offset})}$). S_3 entered to the Page mode and connected S_2 as its slave. After connecting to S_2, it forwarded the packet to S_2, which has only S_6 information. Hence, S_2 entered the Page mode and connected S_6 as its slave. Thus, the proposed LMRO final route construction is shown in Fig. 6.

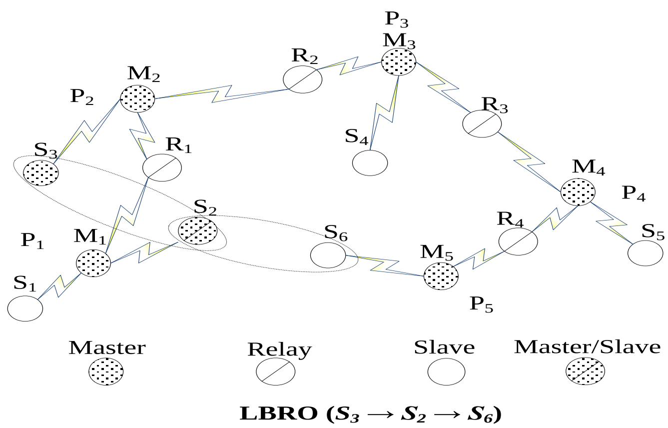


Fig. 6. Route optimization through LMRO

C. Self-organizing Procedure

A node is called routing master if the master itself or any of its node is involved in the selected route between the source and the destination. The main object of Self-organizing procedure is healing between the source and the destination, if a link is disturbed due to node mobility. As each routing master stores the route information that includes node *ID*, k_{offset}, and *LOC* of the members participating in the routing. Node M_1 is the routing masters of the piconet, since S_2 is its member which is participating in the shortest routing path. A piconet contains a routing master (M_i) called routing piconet (*Pi*). If any slave joins any of the routing piconet, BD_Addr, k_{offset}, and LOC of that new node is forwarded to the routing master of the corresponding routing piconet. A sub-route selection procedure is executed if Signal-to-Noise Ratio (SNR) threshold is below ρ. Where ρ = -45*db* is fixed for all routing nodes as below:

$$SNR = \frac{\text{Received power}}{\text{Interferience power}} \geq \rho \tag{10}$$

A link is marked as weak link if SNR is greater than ρ, and the receiver node notifies to sender about weak link status. As shown in Fig. 7(a). a link is created between node S_2 and S_4 due to node mobility the distance has been increased. Thus, the link between S_2 and S_4 become weak which is notified by S_4, shown in Fig. 7(b). On receiving weak link information S_2 sent BD_Addr, LOC, and k_{offset} of S_1 and S_4 to routing master M_1 and requested for its replacement. Once the request is sent S_2 left hold mode and entered into its original mode in P_1 as a pure slave node.

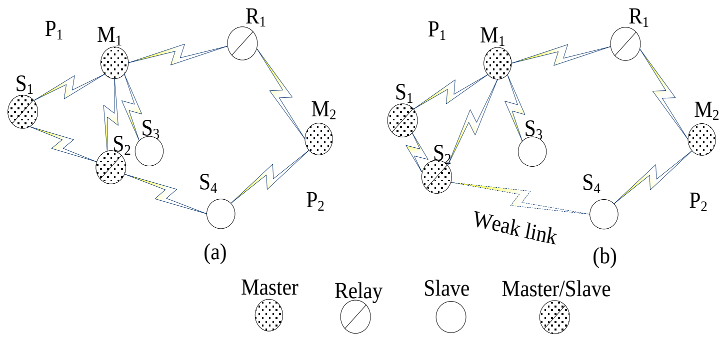


Fig. 7. (a) Original link (b) Weak link

Bluetooth is an ad hoc network, therefore, new nodes may join an existing scatternet. When M_1 received weak link information in the routing path of a Bluetooth scatternet, it verified from NIT which device can be a replacement of the requested device. For the device verification, M_1 executed the device selection procedure. M_1 verified S_3 distance from S_1 and S_4. Meanwhile, S_2 also transmitted weak link information to S_1 and S_4, where S_3 and S_4 entered page and page scan mode respectively to establish the new links. After waiting for a random backoff time, M_1 executed node replacement procedure, and transmitted a member collection packet to S_3 which contains S_1 and S_4 BD_Addr, LOC, and k_{offset}. Upon receiving a member collection information packet, S_3 entered to page scan mode and established the first link with S_1 as a slave. Once the first link is established S_3 executed role switch operation and entered page scan mode and established the second link with S_4, where S_4 played slave role and S_2 played master role as shown in Fig. 7(c).

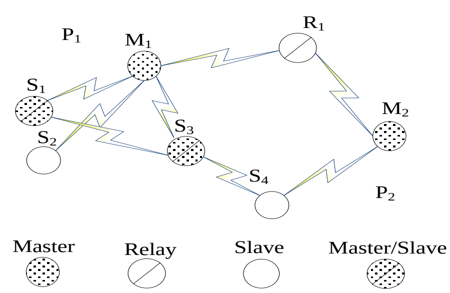


Fig. 7. (c). After replacement procedure

IV. Performance Analysis

This section discusses the simulation environment that is used for evaluating the proposed LMRO protocol and presents the simulation results. Importantly, the performance of the LMRO protocol is analyzed to see whether its objective for efficient inter-piconet communication has been achieved or not. The performance is compared against the standard Bluetooth routing protocols such as the, RRDR [27], LARP [28], and SFBN [29] in terms of route optimization parameters, such as hop count, control packets, delay, guard time, and throughput.

A. Simulation setup

To evaluate the performance, the LMRO protocol is implemented in the UCBT [34], which is an NS-2 based Bluetooth simulator [35]. The UCBT is the only open source Bluetooth simulator that is freely available and supports mesh-shaped scatternets. In addition, the UCBT supports SS and MS bridge role. The UCBT implements the majority of the protocols in the Bluetooth protocol stack. Bluetooth unlicensed Industrial-Scientific-Medical (ISM) band at about 2.4 GHz is used. The Radio Frequency (RF) range of Bluetooth devices is ten meters. Bluetooth 79 RF frequencies are used, where a different frequency is used through the Frequency Hopping Spread Spectrum (FHSS) in each time slot to avoid channel interference. Bluetooth devices use a different frequency in each time slot for communication. The frequency remains the same during the transmission of a packet before transmitting the next packet. Bluetooth devices access medium through the Time Division Duplex (TDD) scheme, which is controlled by the master. Each channel is divided into time slots of T = 625 μs which is synchronized to the clock of the piconet master.

TABLE I. SIMULATION PARAMETERS

Parameter	Value
The number of nodes	10 – 90
Network size	80 x 80 m^2
Communication range	10 m
Power class	B
Traffic model	Constant Bit Rate (CBR)
Node deployment	Random Deployment
Number of pairs	45 pairs
Energy consumption	0.0763 x 10^{-6} J/bit
Packet type	DH3, DH5
Mobility Model	Random waypoint model
Mobility speed	0.5 – 3.0 m/s
Polling algorithm	Round Robin
Bridge scheduling algorithm	MDRP
Packet size	349 Bytes
Inquiry time	10.24 s
Page time	128 – 256 s
Packet interval	0.15 s
Queue length	50 packets
Simulation time	1000 s

The parameters used in the simulation are listed in Table 1. [10, 36]. The confidence interval of simulation was 0.05%. The number of nodes is varied from 10 to 90, and randomly deployed in a simulation area of 80 x 80 m^2. The radio range for a mobile node is 10 meters. Transmitting or receiving energy consumption is set to 0.0763 x 10^{-6} J/bit and the queue length on each link is 50 packets. The Priority-based Round Robin (PRR) algorithm is used for polling, while Inter-piconet communication is achieved through Maximum Distance Rendezvous Point (MDRP) [37]. The Constant Bit Rate (CBR) is used to send 349 byte packets randomly selected sources and destinations. Each node can participate in multiple connections. The Random waypoint mobility model is used for the simulation. Total simulation time is 1000 seconds, where the first 99 seconds are used for scatternet construction, and CBR traffic is started at the 100^{th} second. The simulation is performed 10 times, and results are taken by averaging the obtained results.

B. Simulation results and discussion

From the series of simulation results as described below, it can be concluded that the proposed LMRO routing protocol has outperformed the four contemporary protocols of RRDR, LARP, and SFBN for inter-piconet communication in a scatternet of a Bluetooth network. The LMRO performs route optimization beyond the source and destination. In addition, the LMRO considered the node mobility, hop count reduction, and link repairing. It is analyzed that the RRDR, and LARP route optimization is based on an route search that increases route length in the scatternet. On the other hand, SFBN route construction depends on scatternet efficiency. The simulation results that are presented in the following sub-section are a set of evidence to support the superiority of the LMRO routing protocol. In ad-hoc networks, lifetime is considered the key challenging issue because all the nodes are battery powered and have limited battery. Thus, prolonging network life is important to carry out all the primitive functions of nodes such as: sensing, receiving, transmitting, processing etc. In Bluetooth, multiple slaves wait to utilize a common medium, due to inherited nature of wireless technology. Bluetooth does not allow node contention for simultaneous transmission. The proposed protocol reduced intermediate nodes, therefore, disconnection probability has been reduced and ultimately, overall less system resources consumed.

Hop count refers to the number of intermediate hosts between a source and a destination. Average hop count is calculated through total number of intermediate links between source and destination nodes. Fig. 8. shows the average hop count for all four protocols; it can be observed that LMRO reduces hop count as compared to RRDR, LARP, and SFBN. RRDR does not efficiently reduce route length, as it only considers relay nodes for hop reduction, which increases the path length. Further, LARP depends on a RSP, where it has been found that RSP does not always follow the shortest route. It is analyzed that SFBN protocols is straightforward and easy to implement, but its topology affects scatternet performance by network partitioning. SFBN topology follows Master-slave (MS) bridge policy for inter-piconet communication which stops intra-piconet communication due to master node unavailability. With the LMRO protocol, the shortest route can be found beyond the source and destination nodes in the scatternet. It is observed that LARP and SFBN reduce the number of hops compared to RRDR because it does not consider slave nodes for hop reduction. It can be analyzed that LARP and SFBN has almost similar average hop count for inter-piconet communication. The proposed LMRO considers slave nodes beyond source and destination during route searches and route replies, which gives significant improvement in terms of hop count reduction. The simulation results showed that the proposed LMRO l has reduced hop count between 20% - 50%.

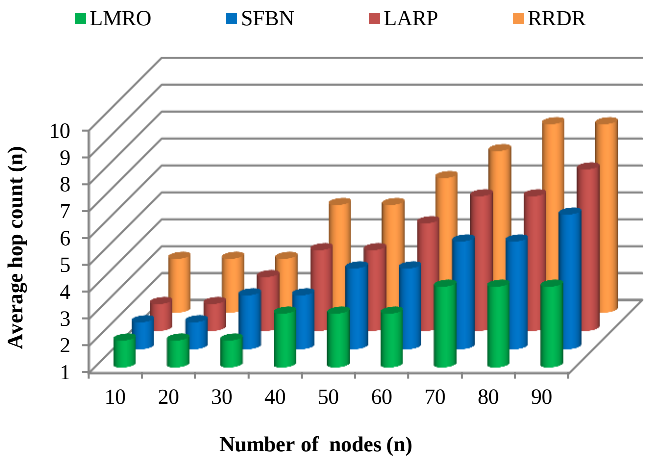


Fig. 8. Average hop count vs. number of nodes

Bluetooth uses different types of control packets for connection activation and information exchange. Total size of information that is used for communication is known as control overhead. Control message overhead is calculated as the sum of bytes in MAC, base-band, NULL, and POLL packets. Every time a message is forward through the network, intermediate devices need to synchronize and exchange control messages. It is observed that a longer route needs more control messages due to the Bluetooth devices' synchronization process. RRDR uses distributed relay reduction with heavy control packets that creates a huge amount of overhead for different mobile nodes. LARP reduces the hop count, but creates an extra amount of message overhead due to longer route selection. In SFBN, master also performs bridge functionality and exchanges more control messages for slot reservation and network maintenance. It is observed more route links break by increasing mobility speed, thus, all four existing protocols start establish new link from Inquiry and Inquiry Scan which consume large number of control packets. In contrast, the proposed LMRO protocol selected the shortest route and repaired damaged links without flooding, therefore, it reduced the control overhead. From Fig. 9. it is observed that the LMRO protocol performs better as compared to all three protocols of RRDR, LARP, and SFBN in terms of control packets.

Throughput is defined as the successful data bytes received by a destination per unit time. Throughput is calculated as total number of bytes received by destination nodes divided by simulation time. As discussed above, all the protocols of RRDR, LARP, and SFBN have neglected the routing link condition. RRDR has tried to reduce the route, but it is only based on relay nodes, and therefore, RRDR did not really optimize the route length. On the other hand, the LARP route depends on RSP, and it has not completely optimized the route length between a source and a destination. LMRO is more efficient than RRDR, LARP, and SFBN in terms of throughput by reducing the guard time, as the guard time affects the throughput on all the existing protocols. There are many chances for the traffic to follow the same link for multiple connections, once a link breaks, it starts heavy flooding problems as that of RRDR, LARP, and SFBN. SFBN has reduced path lengths, however, it suffers from bottleneck nodes which reduces network throughput and partitions network due to the tree hierarchy. As shown in Fig. 10. with passing time all three existing protocols reducing throughput due to link breakage. On the other hand, the proposed LMRO protocol has maintained throughput by performing network maintenance, therefore, the proposed LMRO has 30% to 40% higher throughput as compared to the existing protocols.

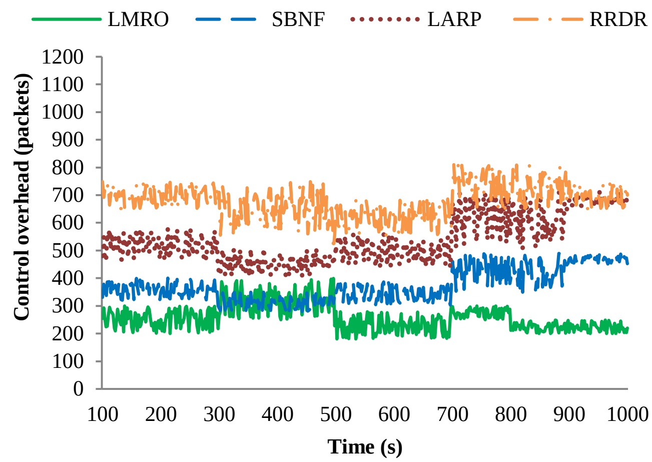


Fig. 9. Control packets vs. simulation time

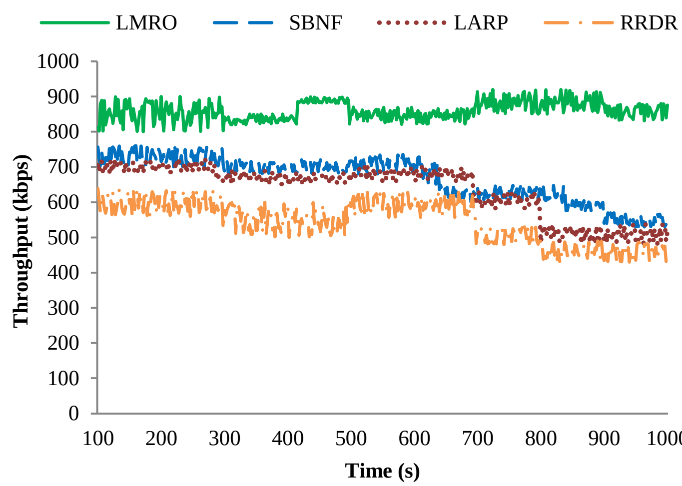


Fig. 10. Average network throughput vs. simulation time

The time required for a bit to be forwarded from a source to a destination is called delay. Average End-to-end delay is the sum of each (packet received time – packet transmitted time) divided by time. If a node leaves its position during transmission, all transmission is aborted. Therefore, a new route connection procedure starts from an inquiry and the inquiry scan which increases transmission delay. Delay in a scatternet highly depends on the number of connections passing through a node (master/relay). A node activation time depends on synchronization time and service time. In the proposed protocol, the master checks the traffic load of each AH in the piconet. If multiple AHs exist, the first priority is given to slave or a lower degree node is selected for new route connection to avoid bottleneck problem. It is analyzed that the average delay of LMRO is less than that of RRDR, LARP, and SFBN. When mobility increases, the delay also increases; this is because frequent node mobility has increased the polling time of the masters. It is observed that a large number of intermediate devices increase delay and link disconnection probability. In addition, large number of devices also increases route length of the randomly selected source and destination. Due to mobility and frequent link breakage, the average end-to-end delay of RRDR LARP, and SFBN is high. Fig. 11. shows the end-to-end delay of different protocols against simulation time. It is observed that the proposed protocol outperforms RRDR, LARP, and SFBN in terms of delay. Generally, a short route length has reduced delay in a network, where LMRO has selected the shortest route in the scatternet and reduced sub-route construction time.

The time required by a node to wait for synchronization with a master/relay is called guard time. During the guard time, a transmission is blocked due to the synchronization process. When the number of nodes increases, the guard time also increases; this is because greater number of nodes increases the polling time of the masters. Since large number of intermediate devices increase guard time, and increase link disconnection probability. Increasing numbers of nodes also increase route length of randomly selected source and destination. As a relay needs 3Δ time for synchronization, it means a message that passes through relay needs 2(3Δ) because a relay synchronizes with two masters. A piconet contains a maximum of eight active devices, and all of the devices need separate slots for uplink (slave to master) and downlink (master to slave) transmissions. It can be analyzed that guard time increases when mobility speed increases. The reason is that a node has to share its time among all the connected masters.

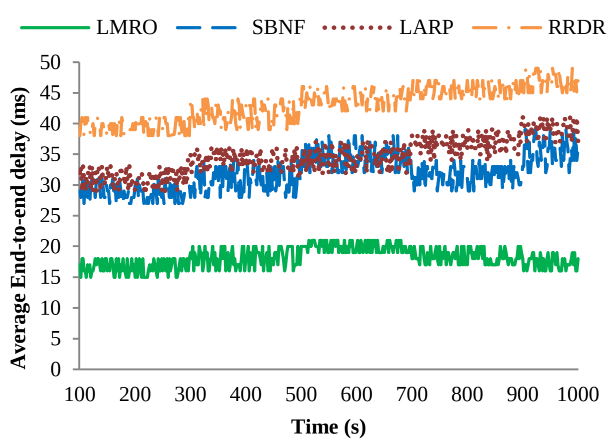


Fig. 11. Total end-to-end delay vs. simulation time

As RRDR, LARP, and SFBN protocols do not consider network maintenance, there are many chances that one node participates in multiple links, and subsequently increases the guard time. The proposed protocol of LMRO tries to find the shortest route, this effort reduces the chances of a single node participating in a large number of links. Fig. 12. shows the effect of the guard time and improves the overall network performance. As mobility increases, the guard time also gradually increases, but it can be observed that LMRO has less guard time as compared to RRDR, LARP, and SFBN.

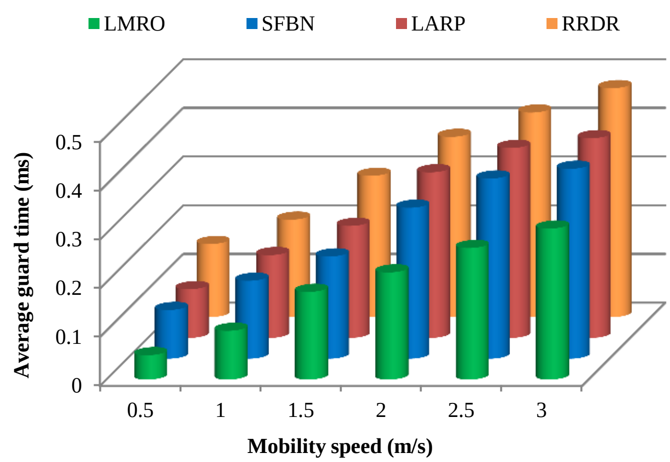


Fig. 12. Guard time vs. average speed

V. Conclusion and Future Work

Bluetooth devices are becoming more popular as modern technology is transferring data onto wireless mediums for access flexibility and user mobility. Specifically, Bluetooth is one of the technologies that is capable enough to provide the last-meter connectivity. However, the inefficient inter-piconet communication in the scatternet topology has led to the overall inefficiency of the Bluetooth communications. This inefficiency is mainly contributed to the delay and control overhead in the inter-piconet scheduling policy. It is analyzed, that existing routing protocols construct a route that is based on a master and relay nodes that increases the number of hops. Furthermore, the existing protocols perform route optimization, but route optimization is based only on the RSP. Therefore, the existing protocols do not reduce an optimum number of hops. This motivates towards the development of a new routing protocol that would reduce the number of hops and repair weak link that ultimately improve the overall system performance. The proposed LMRO protocol finds the best shortest route between a source and a destination. Analytically, the LMRO has reduced the hop count and successfully repaired damaged link between a source and a destination. Empirically, through simulation, the performance of the proposed LMRO protocol is compared against the performance of the RRDR, LARP, and SFBN protocols based on several performance metrics. It was found that the LMRO protocol has outperformed all four protocols in terms of hop count, message overhead, delay, and throughput. Interestingly, the LMRO's throughput has improved in the range of 30% - 40%, and this was achieved by reducing hop count in the inter-piconet routing.

There is still room for future study and development. In the future, more research issues would be addressed based on the proposed study. A more realistic approach would be adopted to adjust a node in a piconet to which it is frequently communicated in order to reduce the scheduling overhead. In addition, the proposed LMRO protocol will be extended to overcome frequent link disconnection problems due to node mobility, which is based on a stable node selection.

ACKNOWLEDGEMENT

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REFERENCES

[1] M. Collotta And G. Pau, "Bluetooth For Internet Of Things: A Fuzzy Approach To Improve Power Management In Smart Homes," Computers & Electrical Engineering, Vol. 44, Pp. 137-152, 2015.

[2] C. Kuor-Hsin, "Bluetooth: A Viable Solution For Iot? [Industry Perspectives]," Wireless Communications, Ieee, Vol. 21, Pp. 6-7, 2014.

[3] F. Reynolds, "Whither Bluetooth?," Pervasive Computing, Ieee, Vol. 7, Pp. 6-8, 2008.

[4] S.-H. Lee And Y.-H. Lee, "Adaptive Frequency Hopping And Power Control Based On Spectrum Characteristic Of Error Sources In Bluetooth Systems," Computers & Electrical Engineering, Pp. 341-351, 2010.

[5] H. Alzaher, Et Al., "Dual-Mode Bluetooth/Wireless Local Area Network Channel-Select Filter For Direct Conversion Receivers," Circuits, Devices & Systems, Iet, Vol. 5, Pp. 189-195, 2011.

[6] C. M. Yu And J. H. Lin, "Enhanced Bluetree: A Mesh Topology Approach Forming Bluetooth Scatternet," Wireless Sensor Systems, Iet, Vol. 2, Pp. 409-415, 2012.

[7] P. Singh And S. Agrawal, "A Servey On Bluetooth Scatternet Formation," In Advances In Computing And Information Technology. Vol. 198, D. Wyld, Et Al., Eds., Ed: Springer Berlin Heidelberg, 2011, Pp. 260-269.

[8] P. Bhagwat And C. Perkins, "Highly Dynamic Destination-Sequenced Distance-Vector Routing (Dsdv) For Mobile Computers," Presented At The Acm Conference On Communications Architectures, 1994. ('94) 1994 Acm Protocols And Applications, 1994.

[9] S. Jung, Et Al., "Bluetorrent: Cooperative Content Sharing For Bluetooth Users," Pervasive And Mobile Computing, Vol. 3, Pp. 609-634, 2007.

[10] T. Hassan, Et Al., "Ring Of Masters (Rom): A New Ring Structure For Bluetooth Scatternets With Dynamic Routing And Adaptive Scheduling Schemes," Pervasive And Mobile Computing, Vol. 4, Pp. 546-561, 2008.

[11] St Bakhsh,Et Al., “Self-Schedule And Self-Distributive Mac Scheduling Algorithms For Next-Generation Sensor Networks”, International Journal Of Distributed Sensor Networks, Pp. 1-8, 2015.

[12] P. K. Sahoo, Et Al., "Novel Route Maintenance Protocols For The Bluetooth Ad Hoc Network With Mobility," Journal Of Network And Computer Applications, Vol. 31, Pp. 535-558, 2008.

[13] L. Xiang, Et Al., "Hierarchical Routing For Large Scale Bluetooth Network," In Networks Security, Wireless Communications And Trusted Computing, 2009. Nswctc '09. International Conference On, 2009, Pp. 415-418.

[14] A. A. S. Alkhrabash And M. Elshebani, "Routing Schemes For Bluetooth Scatternet Applicable To Mobile Ad-Hoc Networks," In Telecommunication In Modern Satellite, Cable, And Broadcasting Services, 2009. Telsiks '09. 9th International Conference On, 2009, Pp. 560-563.

[15] G. Ramana Reddy, Et Al., "An Efficient Algorithm For Scheduling In Bluetooth Piconets And Scatternets," Wireless Networks, Vol. 16, Pp. 1799-1816, 2010/10/01 2010.

[16] S. Tahir, Et Al., "Bluetooth Network Re-Formation Protocol For Reducing Path Length (Bnr)," In Computer & Information Science (Iccis), 2012 International Conference On, 2012, Pp. 755-759.

[17] S. T. Bakhsh, Et Al., "Dynamic Relay Management Protocol For Efficient Inter-Piconet Scheduling In Bluetooth Scatternet," Computers & Electrical Engineering, Vol. 38, Pp. 626-642, 2012.

[18] J.-W. Lin And W.-S. Wang, "An Efficient Reconstruction Approach For Improving Bluetree Scatternet Formation In Personal Area Networks," Journal Of Network And Computer Applications, Vol. 33, Pp. 141-155, 2010.

[19] R. M. Whitaker, Et Al., "Bluetooth Scatternet Formation: A Survey," Ad Hoc Networks, Vol. 3, Pp. 403-450, 2005.

[20] J. P. Dunning, "Taming The Blue Beast: A Survey Of Bluetooth Based Threats," Security & Privacy, Ieee, Vol. 8, Pp. 20-27, 2010.

[21] J. Werb And C. Lanzl, "Designing A Positioning System For Finding Things And People Indoors," Spectrum, Ieee, Vol. 35, Pp. 71-78, 1998.

[22] W. Yunbo, Et Al., "A Study On The Cricket Location-Support System Communication Protocols," In Electro/Information Technology, 2007 Ieee International Conference On, 2007, Pp. 257-262.

[23] F. Subhan, Et Al., "Indoor Positioning In Bluetooth Networks Using Fingerprinting And Lateration Approach," In International Conference On Information Science And Applications (Icisa), 2011, Pp. 1-9.

[24] K. E. Persson, Et Al., "Bluetooth Scatternets: Criteria, Models And Classification," Ad Hoc Networks, Vol. 3, Pp. 777-794, 2005.

[25] G. Aldabbagh, Et Al., "Qos-Aware Tethering In A Heterogeneous Wireless Network Using Lte And Tv White Spaces," Computer Networks, Vol. 81, Pp. 136-146, 2015.

[26] G. Aldabbagh, Et Al., "Distributed Dynamic Load Balancing In A Heterogeneous Network Using Lte And Tv White Spaces," Wireless Networks, Pp. 1-12, 2015.

[27] G.-J. Yu, Et Al., "Relay Reduction And Disjoint Routes Construction For Scatternet Over Bluetooth Radio System," Journal Of Network And Computer Applications, Vol. 30, Pp. 728-749, 2007.

[28] C. Sheng-Wen, Et Al., "A Location-And-Mobility Aware Routing Protocol For Bluetooth Radio Networks," In Pervasive Computing (Jcpc), 2009 Joint Conferences On, 2009, Pp. 137-142.

[29] S. Sharafeddine, Et Al., "A Scatternet Formation Algorithm For Bluetooth Networks With A Non-Uniform Distribution Of Devices," Journal Of Network And Computer Applications, Vol. 35, Pp. 644-656, 2012.

[30] G. Zanca, Et Al., "Experimental Comparison Of Rssi-Based Localization Algorithms For Indoor Wireless Sensor Networks," Presented At The Workshop On Real-World Wireless Sensor Networks, 2008.

[31] F. J. Gonzalez-Castano And J. Garcia-Reinoso, "Bluetooth Location Networks," Presented At The Global Telecommunications Conference, 2002.

[32] F. Subhan, Et Al., "Analysis Of Bluetooth Signal Parameters For Indoor Positioning Systems," Presented At The International Conference On Computer & Information Science (Iccis), 2012.

[33] Y. Gelzayd, "An Alternate Connection Establishment Scheme In The Bluetooth System," Degree Of Master Of Science (Telecommunication Networks), Polytechnic University, 2002.

[34] D. Agrawal And Q. Wang, "University Of Cinicinnati Bluetooth Simulator (Ucbt), ," , Online: Http://Www.Cs.Uc.Edu/~Cdmc/Ucbt/, 2007.

[35] E. Hossain, "The Network Simulator (Ns-2)", Online: Http://Www.Isi.Edu/Nsnam/Ns/Ns-Build.Html, 2014.

[36] O. Al-Jarrah And O. Megdadi, "Enhanced Aodv Routing Protocol For Bluetooth Scatternet," Computers & Electrical Engineering, Vol. 35, Pp. 197-208, 2009.

[37] P. Johansson, Et Al., "Rendezvous Scheduling In Bluetooth Scatternets," In Communications, 2002. Icc 2002. Ieee International Conference On, 2002, Pp. 318-324.

Face Retrieval Based On Local Binary Pattern and Its Variants: A Comprehensive Study

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***Abstract*—Face retrieval (FR) is one of the specific fields in content-based image retrieval (CBIR). Its aim is to search relevant faces in large database based on the contents of the images rather than the metadata. It has many applications in important areas such as face searching, forensics, and identification… In this paper, we experimentally evaluate Face Retrieval based on Local Binary Pattern (LBP) and its variants: Rotation Invariant Local Binary Pattern (RILBP) and Pyramid of Local Binary Pattern (PLBP). We also use a grid LBP based operator, which divides an image into 6×7 sub-regions then concentrates LBP feature vector from each of them into a spatially enhanced feature histogram. These features were firstly tested on three fontal face datasets: The Database of Faces (TDF), Caltech Faces 1999 (CF1999) and the combination of The Database of faces and Caltech Faces 1999 (CF). Good result on these dataset has encouraged us to conduct tests on Labeled Faces in the Wild (LFW), where the images were taken from real-world condition. Mean average precision (MAP) was used for measuring the performance of the system. We carry out the experiments in two main stages indexing and searching with the use of k-fold cross-validation. We further boost the system by using Locality Sensitive Hashing (LSH). Furthermore, we also evaluate the impact of LSH on the searching stage. The experimental results have shown that LSH is effective for face searching as well as LBP is robust feature in fontal face retrieval.**

Keywords*—*Face Retrieval; LBP; PLBP; Grid LBP; LSH

I. Introduction

The principle of face retrieval problem is the comparison of faces so that those which higher "likelihood" will near the top of result list. In practice, these "likelihood" parameters are presented by a number, which is calculated by a distance function. Next problem is to quantify the faces in the way that a computer can understand. A face can be seen as a combination of smaller part such as eyes, nose, and lips. From that assumption, our approach falls into global features because they can manifest the relative position of these parts in a face or else the global shape. Furthermore, LBP feature can characterized local object appearance rather well. Finally, we choose Euclidean distance to compare LBP feature vector due to the simplification in implement and its low computation cost.

Despite having applications in important areas (face finding, medical, forensics, etc.), retrieving images of faces with high performance in real-world condition is a difficult task due to technical and practical challenges. Beside semantic gap, there are challenges that we should consider when designing a face retrieval system. The first challenge is measuring similarity among images. This was done by compare their feature vector.

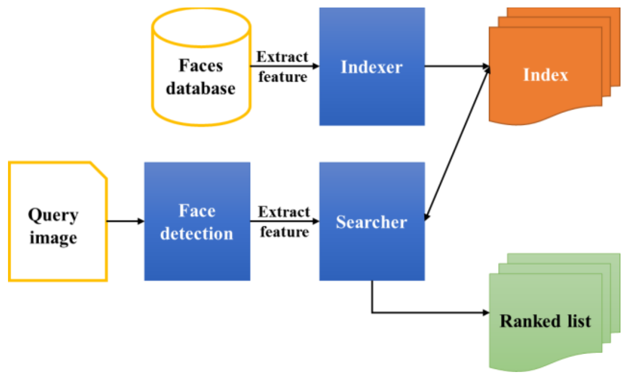

Fig. 1. Flowchart of a face retrieval system

A good method will increase the performance of system while maintaining the computational time. The next challenge is about how good is your system work in real life. It is difficult to design the system that work well in any conditions, due to broad domains (faces of many people in database), high variance of content (images captured in daylight/night, bad weather/good weather, indoor/outdoor…), capture setting (high/low brightness, HDR, etc.), among many others. Finally, understanding of user needs and intentions is the key. This involved in user interface as well as accuracy of the system. For example, face retrieval applications in forensics which required high accuracy and fast search time to find criminal in very large database is different with the applications for finding some famous people look like you which easy to use and do not require a good accuracy.

A face retrieval system consist of indexing, organizing, annotating, and retrieving visual information about faces. Its goal is to retrieve desired face images from the given information (a face image). In this test, we concern the effect of LBP and its extension on indexing and retrieving to find out if good features can increase the system performance. In Figure 1, we introduced a face retrieval system that focus on the important of feature extraction and indexing process. They are the key issues due to the role of index in FR system. Feature extraction decides what feature(s) to be save in the index while the indexing process influent the way of searcher works and the execution time of searching process. In our tests, we used pre-cropped face images so there is no use of face detection module. In application view, this module is needed for extracting face from user provided image. We can easily build it by using existing function from OpenCV library.

The rest of the paper is organized as follows. Firstly, we present a face retrieval system designed to work with global features. This system focuses mainly on the indexing process because it decides how the searching process occurred. In addition, time in FR is an important factor so the way index was built wills greatly influent searching time. Secondly, we empirically evaluate LBP and its variants for face retrieval on several dataset that focus on fontal face. Furthermore, we also test our approach on the Labeled Faces in the Wild (LFW) dataset has some changes, for example, difference in facial detail or facial expression… Results from these dataset help understanding the effect of dataset properties on the system. LFW puts the face retrieval system in real-world condition by using image collected around the web. Testing on this dataset will determine the practical applicability of tested features. Thirdly, we boost the system by using LSH. We also conducted tests to prove its ability to the traditional nearest neighbor method. The tests include indexing time, searching time, and searching time on different size of dataset.

The rest of this paper is structured as follows. In section II, we present related works. The original LBP and its variants are introduced in section III. We discuss the indexing process of FR in section IV. Experimental result and discussion are showed in section V. Finally, section VI draws conclusions of our work and indicates future studies.

II. Related Works

A. Content-based image retrieval

The origin of the term "Content-based image retrieval" was mentioned in [1] that Kato (1992) used it to describe his tests in automatic retrieval of images from a database using color and shape feature. Since then, the term has been widely used to define the process of retrieving images from a large collection using features that can be automatically extracted from the images. These features can be primitive or semantic but the extraction process must be predominantly automatic.

The vital difference between CBIR and classical information retrieval (IR) is the image databases differ from text databases. A digital image can be seen as an array of pixel intensities which we cannot directly understand while text (collection of words stored as ASCII strings) is logically organized by the author. When the search process occur on the databases, IR searcher use metadata or full-text in the index and CBIR searcher use a distance function to measure the similarity of the query image's feature(s) among images' feature(s) in the databases. Therefore, searching images by keywords from manually assigned is not CBIR.

There are keys issues that was mention in [1] as the important needs when designing a CBIR system:

- Understanding of user's needs and intention.
- Choosing feature(s), which balance in computing cost and retrieval performance.
- Providing compact storage for bulk images as well as efficient ways to access, update, and delete them.
- Designing a good method that reflects human similarity judgments to match query and stored images.

CBIR uses many methods from the field of image processing and computed vision since it involved these fields in feature extraction, preprocessing images (resizing, adjusting contrast, cropping…)… We can think of CBIR as a combination of databases with these methods in a way that created a working system for searching images based on theirs content.

B. Face retrieval

We can simply regard a face retrieval system as a CBIR system that works with raw pixel values from face images. In 1987, a face retrieval application, FRAME – Face Retrieval and Matching Equipment, was introduced to help the police in their investigation [2]. In the early form of FR presented in [3], the indexing stage is not fully automatic due to the lack of good face component detection. So there is a module that allows user to add addition information and modify the result of face's components detection. There also some limitations, for example, the way of features extraction was complicated and computation cost, the system was still depend on supplement information as text to increase retrieval performance… We can stage that this is not truly a CBIR system but this work has pointed out the important parts of a face retrieval: feature extraction, way of storing and accessing images in the database, a distance function to measure image similarity, how we use an image as a query to search on the database.

Later in 1994, MIT's Media Laboratory presented a famous FR system that its core is the eigenfaces database [4 – 5]. The special thing about this system is it was trained with large face images database to compute 20 features (called eigenfeatures). These features can characterize any human face in higher level of information which more robust and brought better precision than raw pixel values. The drawbacks of this method are the system needs training before further process, and it cannot completely automated for broad domains of images [6].

C. Local Binary Pattern

LBP was first introduce in [7] as a powerful feature for texture classification. It was later use for solving face recognition [8 – 10] due to its ability to represent face image [10 – 12]. It also used for facial expressions recognition [13], gender classification [14], human detection [15], etc. It also combined with block-based method for image retrieval [16]. Many works were done to extend its invariant against rotation [17] and scale [18].

III. LBP and Its Variants

In this section, we will brief introduction about the original LBP and its extensions: Rotation Invariant Local Binary Pattern, Pyramid of LBP and Grid LBP. The content of each sub-section included the idea behind, the process of calculating histogram for each version.

A. Local Binary Pattern

A LBP operator considered each pixel has a code (called Local Binary Patterns codes or LBP codes) which was calculated by thresholding its 3×3 neighborhood with the center value (Figure 2). As a consequence, this make LBP invariant against gray-scale. It also presented local primitives such as curve edges, spots, corner and so on [11].

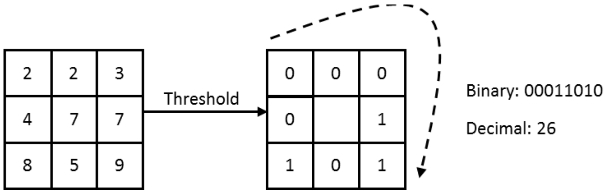

Fig. 2. A basic LBP operator

In Figure 3, the $3x3$ neighborhood was expanded to capture dominant feature with large-scale structures. The neighborhood can be denoted by a pair (P, R) where P is the sampling points on a circle of radius of R. Therefore, there are 2^P different output values.

Oajala's study [7] has proved that some bins in LBP histogram contain more information than others. These bins is called uniform patterns. A LBP code must contain at most two bitwise transitions from zero to one or vice versa when the binary string is considered circular (Figure 5). It was shown that $(8, 1)$ neighborhood accounting nearly 90% of all patterns and about 70% for in the $(16, 2)$ neighborhood.

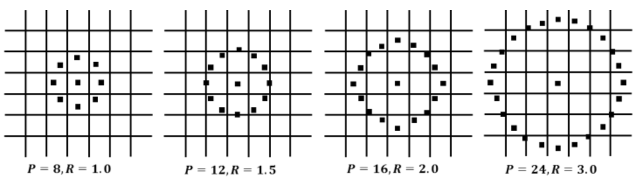

Fig. 3. Extended LBP operator compare to the basic one

A histogram of an image labeled by LBP operator can be detail as follows:

$$H_i = \sum_{x,y} I(f_l(x, y) = i), \;\; i = 0, \dots, n-1 \qquad (1)$$

here n is the number of total different output generated by the LBP operator as follows:

$$I(A) = \begin{cases} 1 \;\; if \;\; A \; is \; true \\ 0 \; if \;\; A \; is \; false \end{cases} \qquad (2)$$

This LBP histogram is statistical since each local micro-patterns in Figure 3 have their own LBP code and creating a histogram over the whole image will presented their distribution. Therefore, it can describe image characteristics.

B. Rotation Invariant Local Binary Pattern

In Figure 4, we can see that an edge pattern has LBP code of 26 but if we rotate this pattern 90° clockwise its LBP code is 7. Therefore, rotation has distinct these pattern into different bins.

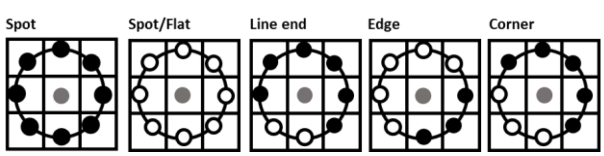

Fig. 4. Examples of texture primitives presented by LBP (white circles mean zeros and the black circles mean ones)

In generality, if we compare an image with its rotated one, computer will consider these two images different base on their LBP histogram. To extended LBP ability against rotation, Ojala et al [17] has provided a simple yet effective operator call LBP_8^{ri36} . As in Figure 6, this operator use (8,1) neighborhood to generate 36 different values that represent 36 unique rotation invariant LBP patterns. We can obtain these codes easily by rotating LBP code:

$$LBP_{8,1}^{ri} = \min\{ROR(LBP_8, i) | i = 0,1, \dots, 7\} \qquad (3)$$

where $ROR(x, i)$ is a circular bit-wise right shift.

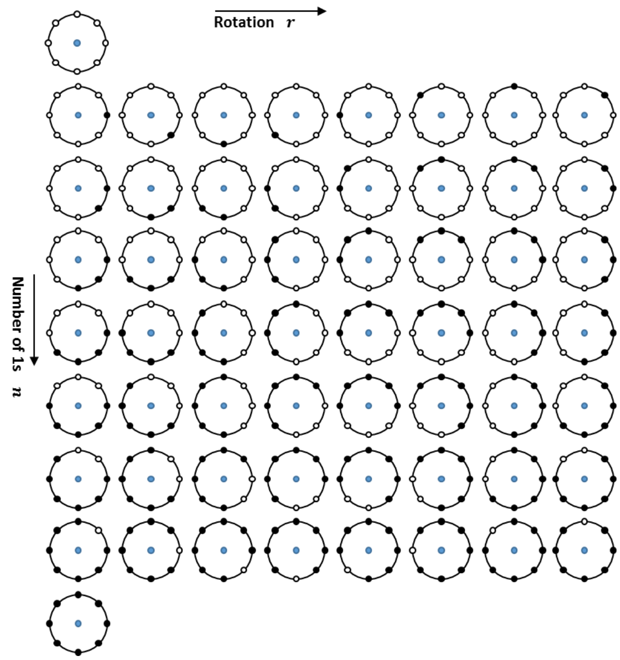

Fig. 5. All uniform pattern of $LBP_{8,1}$ operator

Also in [17] mention this operator is not good at discrimination due to the distraction of some patterns to the analysis and crude quantization of the angular space at 45° intervals. To overcome this problem, 36 patterns were reduced to 9 patterns which were numbered in Figure 6. The process of calculating these patterns is denoted by:

$$LBP_{8,1}^{rui2} = \begin{cases} \sum_{i=1}^{8} s(g_i - \; g_0) \; if \; U(LBP_{8,1}) \leq 2 \\ \quad 9 \qquad\qquad\qquad otherwise \end{cases} \qquad (4)$$

where:

- $s(x) = \begin{cases} 1, \; x \geq 0 \\ 0, \; x \leq 0 \end{cases}$, g_0 is the center pixel and g_i is its 3×3 neighborhood.
- $U(c)$ is a function that calculate number of spatial transitions in $LBP_{8,1}$ binary code which was denoted by:

$$U(LBP_{P,R}) = |s(g_{P-1} - g_c) - s(g_0 - g_c)| + \sum_{p=1}^{P-1} |s(g_p - g_c) - g_c| \quad (5)$$

There is a LBP_{16}^{riu2} operator which is consider 5 x 5 square contain 16 pixel neighborhood but we don't go into detail about it since we use the original LBP operator in our test.

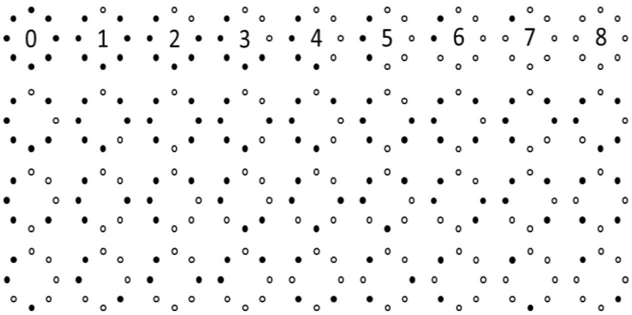

Fig. 6. Observed 36 $LBP_{8,1}^{ri}$ patterns. Black and white dot indicate to bit value of zeros and ones

C. Pyramid of LBP

LBP was extended its feature against texture resolution by cascading the hierarchical spatial pyramids information of LBP [18]. Detail of this process was showed in Figure 7. Firstly, edge contours was extracted from input image by using Canny edge detection which using 3×3 Sobel filter without Gaussian smoothing. Then the image was partition into l level. In each level, instead of calculating gradients, we use $LBP_{8,1}^{ri}$ operator to get histogram from sub-region in that level. Finally, these histograms was concentrated by order of level to form a PLBP feature vector.

D. Grid LBP

A face image is a combination of eyes, nose, lip… each component can be seen as a micro-pattern which effectively presented by the LBP histogram. This can be done by equally dividing face images into small regions $R_0, R_1, \dots, R_m$. The LBP histograms obtained from these regions are concatenated into a spatially enhanced, single feature histogram, which was defined as follows:

$$H_{i,j} = \sum_{x,y} I\{f_l(x,y) = i\} I\{(x,y) \in R_j\} \quad (6)$$

where $i = 0, \dots, n-1$, $j = 0, \dots, m-1$, f_l is an image labeled by using LBP operator.

The relative position of each sub-regions' histogram indicated their location on the face image. This represented global shape of face images as well as the local texture. Therefore, it is perceptive that LBP feature can represent face images [10 – 12]. Following the setting in [10], we choose $LBP_{8,1}^{u2}$ operator and divide face images into 6x7 sub-regions (Figure 8). Thus the final histogram will have the length of 2478 (59x42).

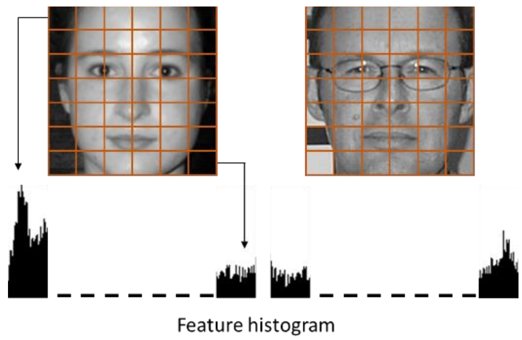

Fig. 8. Illustration of applying the grid 6x7 on images

IV. Indexing

To boost the searching process in trade-off of low computation and space, we use locality sensitive hashing. The idea behind LSH [19] is using feature vectors to create random projections then combined them into a hash string. A LSH function map a feature vector $v \in \mathbb{R}^d$ to a collection of integer $h_1 \dots h_k$ that each integer was calculate as follows:

$$h_i(v) = \left\lfloor \frac{a_i + b_i}{w} \right\rfloor, i \in \{1,2,3 \dots, k\} \quad (8)$$

where $a_i \in \mathbb{R}^d$ is a vector which created by random independent values from a normal distribution, the constant $w \in \mathbb{R}^+$ affects the granularity of the results and a random, the uniformly distributed number $b_i \in [0, w)$.

There are different ways of using LSH depend on types of problem. A more detail can be found in [20]. In retrieval problem, these parameters: a_i, b_i, w and k were initialized once with unchanged value before indexing. In searching stage, due to the use of L_2 distance (Euclidean distance), we assume two images can be used for nearest neighbors if there are m which $m < k$ matched hashes of hash tuples.

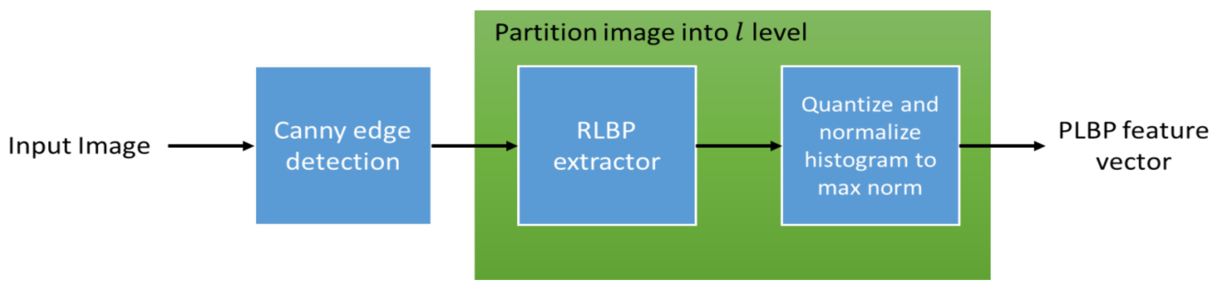

Fig. 7. The process of extracting PLBP feature vector

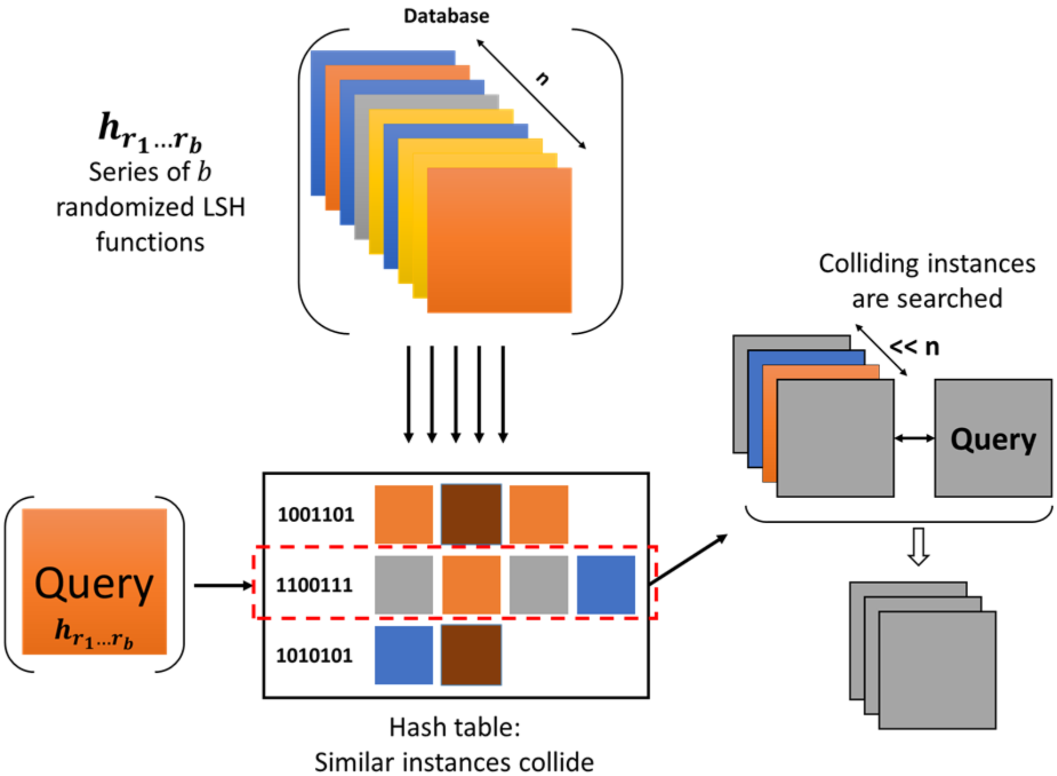

Fig. 9. Illustration of LSH works in the retrieval system

For implementation, a hash bundle was randomly generated before using in indexing and searching. To draw normally distributed random numbers for a_i, the Box-Muller [21] transform was used as follows:

$$\begin{aligned} z_0 &= \sqrt{-2\ln(k_1)}\cos(2\pi k_2) \\ z_1 &= \sqrt{-2\ln(k_1)}\sin(2\pi k_2) \end{aligned} \tag{9}$$

where z_0, z_1 are variables for a_i and $k_1, k_2 \in (0,1]$ are uniformly distributed random numbers.

In the indexing process, after feature vectors obtained from feature extractor, each will be projected into hashes. Then information represent for an image (path, feature vector, hashes) is packed. To index that image, indexer considers hashes information from package as a string so that it can index this string in an inverted index. The searching process on existing index was done by generating hashes from query image's feature vector and using it as a string query. Result of this process is a list of items (each item considered as a package) that later sorted based on the similarity of query image's feature vector to each item's feature vector.

V. Experimental Results

A. Datasets

The database of faces (TDF) [22] includes images of 40 distinct subjects. Each subject has ten different images (92×112 pixels), which each image was taken in dark background. This dataset features the varying in lighting, facial expression (open / closed eyes, smiling / not smiling) and facial details (glasses / no glasses) in its images.

Caltech Faces 1999 (CF1999) [23] differ from previous datasets by adding backgrounds and facial expressions to its images. However, there is no difference in facial detail. This database has 447 images (896×592 pixels) of 27 unique people. We later crop and resize images in this database so that only frontal face in the image.

Combination of CF1999 and TDF (CF) was created for: testing the sustainability of LBP features against the increasing of the number of images and the diversity of data properties.

Labeled Faces in the Wild (LFW) [24] contain 13,233 copped images (64×64 pixels) which were collected around the web. All the images were taken in real-world condition. As we observed, these images also difference in face poses, ages, blur / not blur… That make this database far more challenge than any database that we used in the test.

B. Mean Average Precision (MAP)

To measure the retrieval effectiveness based on queries result we use MAP, which was denoted as follows:

$$MAP = \frac{1}{Q}\sum_{q=1}^{Q}\frac{1}{X}\sum_{1}^{R}\frac{i}{r_i} \tag{7}$$

where Q is the number of queries, i is the number of correct items among first R recommendations, and r_i is the position (start from 1) of ith item in the recommendation list which has R items ($1 \leq r_i \leq R$). If a person has $x = 5$ correct images but we request a list of $R = 10$ items then $X = x$ else $X = R$. Equation (7) means that the more correct items appear in recommendation list and the higher their positions in this list, the higher MAP return.

C. Evaluation Framework

We prepared images of each dataset for further stages by conduct a preprocessing stage that included cropping, resizing (using Lanczos algorithm) and converting to gray scale. After that these images was divided into three equal parts, two (as training set) for indexing and one (as testing set) for searching. The evaluation of a dataset was ended when all parts was used for querying which means after we done querying with first part, the process (indexing and searching) was repeated with second part (the rest two part was used for indexing) and then with final part.

The features we used in our tests: original local binary pattern ($LBP_{8,1}$ or LBP), uniform local binary pattern (ULBP or $LBP_{8,1}^{u2}$) , pyramid of local binary pattern (PLBP), pyramid of uniform local binary pattern (PULBP uniform or $PLBP^{u2}$), rotation invariant local binary pattern (RILBP or $LBP_{8,1}^{ri}$), uniform rotation invariant local binary pattern (URILBP or $LBP_{8,1}^{riu2}$) and grid $LBP(6 \times 7)$.

D. Results and disscustion

We have done some tests to show the computation trade-off with/without using LSH. The result of LWF has more weight than the rest in Table I because we usually deal with large image database in real-world application. The 63.3% is lower search time of LSH method is significant compare with small increasing of indexing time as showed in Table II.

TABLE I. AVERAGE EXECUTION TIME OF EACH QUERY IN EACH DATASET (MILLISECONDS / QUERY)

Method \ Dataset	TDF	CF1999	CF	LFW
Without LSH	11.93	13.48	22.15	443.48
With LSH	37.40	44.43	80.68	162.72

The results in Figure 10 have showed the effectiveness of LSH with traditional method (nearest neighbor). We timed 500 queries on different dataset size from 500 to 12000 images. Each query will return a list of 50 items (recommenced faces). Image used in query and dataset are randomly took from LWF dataset. It is clearly that traditional method is good if the size of dataset is under 4000. Beyond that point, the execution time rapidly grown while the time of LSH slightly increase and remain under 180 milliseconds/query even if the size is 12000 images.

TABLE II. AVERAGE INDEXING TIME OF EACH IMAGE IN EACH DATASET (MILLISECONDS / IMAGE)

Method \ Dataset	TDF	CF1999	CF	LFW
Without LSH	15.10	8.90	8.3	3.89
With LSH	17.53	9.47	9.19	4.23

We conducted the tests with different number of returned items from a query. This will show how probability of finding proper faces changes when you continue to look further at the list. In the later part, we will mainly use MAP results of the list of 10 items. There also an illustration of the result of a query from our system in Figures 11 and 12. Fig.11 shows some results from these queries that use $\boldsymbol{LBP_{8,1}^{u2}}$ $(\mathbf{6 \times 7})$ and $\boldsymbol{LBP}$. Figure 12 shows some results from these queries that use on $\boldsymbol{PLBP}$ and $\boldsymbol{RILBP}$. These results show the power of $\boldsymbol{LBP_{8,1}^{u2}}$ $(\mathbf{6 \times 7})$ and $\boldsymbol{PLBP}$ compare to $\boldsymbol{LBP}$ and $\boldsymbol{RILBP}$, respectively.

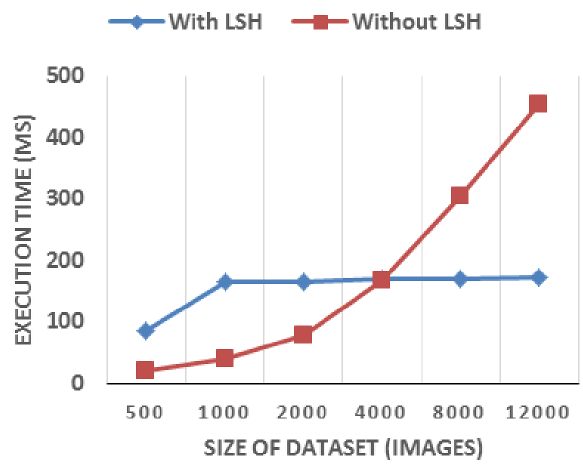

Fig. 10. Average execution time of each query in different dataset size (milliseconds)

Overall, operator that involved parting image into smaller region is the best method. It was showed that $\boldsymbol{PLBP}$, $\boldsymbol{PLBP^{u2}}$ and $\boldsymbol{LBP_{8,1}^{u2}}$ $(\mathbf{6 \times 7})$ yield better result than the others. The MAP in LFW dataset is very low compare to the results of other datasets but it showed that in general, the uniform version is better and image partition greatly improved retrieval performance.

TABLE III. MAP OF "CF1999" DATASET

Feature	Number of retuned items				
	10	20	30	50	70
$LBP_{8,1}$	0.2824	0.2499	0.2693	0.2898	0.2987
$LBP_{8,1}^{u2}$	0.2756	0.2436	0.2628	0.2831	0.2924
$LBP_{8,1}^{ri}$	0.1421	0.1305	0.1463	0.1670	0.1781
$LBP_{8,1}^{riu2}$	0.1208	0.1121	0.1258	0.1433	0.1532
$PLBP$	0.3375	0.2914	0.3191	0.3429	0.3544
$PLBP^{u2}$	0.3755	0.3255	0.3529	0.3759	0.3864
$LBP_{8,1}^{u2}$ (6×7)	0.8540	0.7869	0.8008	0.8078	0.8111

The special feature of CF1999 is its images were taken different facial expression and backgrounds. Table III showed that $\boldsymbol{LBP_{8,1}^{ri}/LBP_{8,1}^{riu2}}$ operator that indicate image information into small number of bins (36 bins of $\boldsymbol{LBP_{8,1}^{ri}}$ and 9 bins of $\boldsymbol{LBP_{8,1}^{riu2}}$) has the lowest MAP score by 0.1421/0.1208. $\boldsymbol{LBP_{8,1}/LBP_{8,1}^{u2}}$ performs two times better than $\boldsymbol{LBP_{8,1}^{ri}/LBP_{8,1}^{riu2}}$ based on MAP score but its MAP still very low. In this dataset, uniform version of $\boldsymbol{PLBP}$ operator is the only operator that perform better that its original version.

$LBP_{8,1}^{u2}\ (6\times7)$ has proven its effectiveness in this case with the highest MAP score of 0.8540, which is over two times than the second high score (0.3755 of $PLBP^{u2}$).

TABLE IV. MAP OF "TDF" DATASET

Feature	Number of retuned items				
	10	*20*	*30*	*50*	*70*
$LBP_{8,1}$	0.4121	0.4427	0.4539	0.4651	0.4702
$LBP_{8,1}^{u2}$	0.4100	0.4406	0.4516	0.4628	0.4680
$LBP_{8,1}^{ri}$	0.1868	0.2180	0.2348	0.2514	0.2583
$LBP_{8,1}^{riu2}$	0.1686	0.1993	0.2134	0.2280	0.2348
$PLBP$	0.4411	0.4735	0.4845	0.4956	0.5005
$PLBP^{u2}$	0.4740	0.5047	0.5169	0.5277	0.5325
$LBP_{8,1}^{u2}$ (6×7)	0.6490	0.6738	0.6825	0.6891	0.6923

TDF expanded CF1999 by adding different facial details and some side movement of face into its content but its image background is constant (dark background). In Table IV, $LBP_{8,1}/LBP_{8,1}^{u2}$ performed nearly 250% better by 0.4411/0.4740 compare to its MAP in CF1999. There is also a slight increase in MAP of $LBP_{8,1}^{ri}/LBP_{8,1}^{riu2}$ but its score is still very low by 0.1868/0.1686. Same as CF1999 dataset, $PLBP^{u2}$ has higher MAP than $PLBP$ and they still hold the second and third high score. While others operator showed their improvement in MAP, $LBP_{8,1}^{u2}\ (6\times7)$ decreased significantly from 0.8540 in CF1999 to 0.6490 in TDF.

TABLE V. MAP OF "CF" DATASET

Feature	Number of retuned items				
	10	*20*	*30*	*50*	*70*
$LBP_{8,1}$	0.3371	0.3366	0.3517	0.3664	0.3730
$LBP_{8,1}^{u2}$	0.3322	0.3319	0.3471	0.3620	0.3687
$LBP_{8,1}^{ri}$	0.1379	0.1439	0.1554	0.1682	0.1751
$LBP_{8,1}^{riu2}$	0.1282	0.1339	0.1448	0.1560	0.1625
$PLBP$	0.3731	0.3617	0.3760	0.3908	0.3974
$PLBP^{u2}$	0.4146	0.4021	0.4184	0.4328	0.4394
$LBP_{8,1}^{u2}$ (6×7)	0.7549	0.7326	0.7424	0.7492	0.7520

CF further tests LBP and its extensions by put all the properties of CF1999 and TDF together in a single dataset. From the result in Table V, it can be seen that except $LBP_{8,1}^{u2}\ (6\times7)$ and$LBP_{8,1}^{ri}/LBP_{8,1}^{riu2}$, the entire MAP score of others operator is higher than CF1999's scores and lower than TDF's scores. $LBP_{8,1}^{ri}/LBP_{8,1}^{riu2}$ continue to show its poorly perform in this dataset by the lowest MAP of 0.1379/0.1282. In the other side, $LBP_{8,1}^{u2}\ (6\times7)$ survived the test and showed the better score than TDF dataset.

We put LBP and its extension in to real-world test with LFW dataset. This dataset included previous datasets properties and real life challenges: different light setup; blur, noise, many faces are partly covered, same person but different ages. All the operator and method perform very poorly. Table VI showed that none the MAP scores in this dataset is over 0.002. Except some result that show the MAP scores from the list of 50 – 70 items of $LBP_{8,1}/LBP_{8,1}^{u2}$. This dataset presented the trend that the uniform version has higher MAP than the original.

TABLE VI. MAP OF "LFW" DATASET

Feature	Number of retuned items				
	10	*20*	*30*	*50*	*70*
$LBP_{8,1}$	0.0056	0.0042	0.0038	0.0035	0.0034
$LBP_{8,1}^{u2}$	0.0057	0.0042	0.0036	0.0033	0.0031
$LBP_{8,1}^{ri}$	0.0033	0.0024	0.0021	0.0019	0.0019
$LBP_{8,1}^{riu2}$	0.0036	0.0027	0.0024	0.0021	0.0020
$PLBP$	0.0047	0.0035	0.0030	0.0027	0.0026
$PLBP^{u2}$	0.0059	0.0043	0.0038	0.0033	0.0031
$LBP_{8,1}^{u2}$ (6×7)	0.0189	0.0128	0.0106	0.0089	0.0081

In the terms of user, we likely look for the correct items in first 10–20 results. So we statistically count number of queries that there is no correct item in their first 10 returned items. Then we divided them to total of queries in each dataset. From Table VII, we can find out that which feature is better when using in real life application. $LBP_{8,1}^{u2}\ (6\times7)$ continue to show its impressive ability in practice, its error on first three dataset always below 1% and despite high error rate in LFW dataset, it has the lowest error rate among the tested features. There also two potential features that can be used in practice although their MAP in previous test was low: $PLBP$ and $PLBP^{u2}$. Their error rate below 10% expect in LFW dataset. $PLBP^{u2}$ has a competitive error rate with $LBP_{8,1}^{u2}\ (6\times7)$ by 89.51% to 82.51%. $LBP_{8,1}^{ri}$ and its uniform version have the highest error rate, over 20% in most cases.

TABLE VII. ZERO MAP AT FIRST 10 RETURNED ITEMS IN PERCENTAGE (%)

Feature	Dataset			
	CF1999	*TDF*	*CF*	*LFW*
$LBP_{8,1}$	13.03%	5.00%	8.64%	90.95%
$LBP_{8,1}^{u2}$	12.58%	5.00%	8.64%	90.80%
$LBP_{8,1}^{ri}$	21.57%	16.25%	23.79%	93.28%
$LBP_{8,1}^{riu2}$	22.92%	16.75%	25.80%	93.41%
$PLBP$	8.76%	5.50%	9.70%	91.97%
$PLBP^{u2}$	8.09%	4.00%	7.46%	89.51%
$LBP_{8,1}^{u2}$ (6×7)	0.67%	0.50%	0.59%	82.41%

In general, we can not use LBP and its extensions in practice but there are two feature that showed their promise potential $LBP_{8,1}^{u2}\ (6\times7)$ grid and $PLBP^{u2}$. The biggest challenges these features encountered so far are: (1) many photo was taken in different backgrounds; (2) skewness make the matching between face images even harder since this break the relation of texture position; (3) blur, noise cause the loss of texture information; (4) different facial expression and detail.

VI. CONCLUSION

In this paper, we present our result of LBP and its variant in a FR system. We have been evaluated on three fontal faces datasets. Each dataset has unique properties that represent challenges when work with face images. It has been proved that $\boldsymbol{LBP_{8,1}^{u2}}$ $(\mathbf{6 \times 7})$ overpowered the rest in all test. Further tests in LFW showed that the lack of skewness invariant as well as bur, facial expression and noise has a huge drawback on all tested features performance. High error rate in LFW dataset shows that we need to overcome these problems before apply $\boldsymbol{LBP}$ features on real-world application. We also find out that $\boldsymbol{PLBP}$ can be as well as $\boldsymbol{LBP_{8,1}^{u2}}$ $(\mathbf{6 \times 7})$ from user perspective. Next, the key contribution is that our system can stand against the increasing in the size of dataset and its properties without sudden drop in MAP. Finally, LSH is an ideal choice when designing a FR system that works with large database. However, our system also has some limitations. We have observed that skewness in face image a great influence in retrieval performance and our approach shows its weakness in real-world condition that will be considered in the next works.

In the future, we will consider the fusion of different features such as HOG, learning feature… As well as, we also study face alignment and 3D face modeling to improve the performance in real-word dataset.

Fig. 11. Some results of the queries from our system on $\boldsymbol{LBP_{8,1}^{u2}}$ $(\mathbf{6 \times 7})$ and $\boldsymbol{LBP_{8,1}}$ operator

Fig. 12. Some results of the queries from our system on $PLBP$ and $RILBP$ operator

References

[1] Eakins, John P., and Margaret E. Graham. "Content-based image retrieval, a report to the JISC Technology Applications programme." 1999.

[2] Craw, Ian, H. Ellis, and J. Rowland Lishman. "Automatic extraction of face-features." Pattern recognition letters 5.2, pp 183-187, 1987.

[3] Bach, Jeffrey R., Santanu Paul, and Ramesh Jain. "A visual information management system for the interactive retrieval of faces." Knowledge and Data Engineering, IEEE Transactions on 5.4, pp 619-628, 1993.

[4] Turk, Matthew A., and Alex P. Pentland. "Face recognition using eigenfaces." Computer Vision and Pattern Recognition, IEEE Computer Society Conference on. IEEE, 1991.

[5] Pentland, Alex, Baback Moghaddam, and Thad Starner. "View-based and modular eigenspaces for face recognition." Computer Vision and Pattern Recognition, 1994. Proceedings CVPR'94., 1994 IEEE Computer Society Conference on. IEEE, 1994.

[6] Gupta, Amarnath, and Ramesh Jain. "Visual information retrieval." Communications of the ACM 40.5, 70-79, 1997.

[7] Ojala, Timo, Matti Pietikäinen, and David Harwood. "A comparative study of texture measures with classification based on featured distributions." Pattern recognition 29.1, pp 51-59, 1996.

[8] Ahonen, Timo, Abdenour Hadid, and Matti Pietikainen. "Face description with local binary patterns: Application to face recognition." Pattern Analysis and Machine Intelligence, IEEE Transactions on 28.12, pp 2037-2041, 2006.

[9] Liao, Shengcai, et al. "Learning multi-scale block local binary patterns for face recognition." Advances in Biometrics. Springer Berlin Heidelberg, pp 828-837, 2007.

[10] Ahonen, Timo, Abdenour Hadid, and Matti Pietikäinen. "Face recognition with local binary patterns." Computer vision-eccv 2004. Springer Berlin Heidelberg, pp 469-481, 2004.

[11] Hadid, Abdenour, Matti Pietikäinen, and Timo Ahonen. "A discriminative feature space for detecting and recognizing faces." Computer Vision and Pattern Recognition, 2004.

[12] Feng, Xiaoyi, Abdenour Hadid, and Matti Pietikäinen. "A coarse-to-fine classification scheme for facial expression recognition." Image Analysis and Recognition. Springer Berlin Heidelberg, pp 668-675, 2004.

[13] Zhao, Guoying, and Matti Pietikainen. "Dynamic texture recognition using local binary patterns with an application to facial expressions." Pattern Analysis and Machine Intelligence, IEEE Transactions on 29.6, pp 915-928, 2007.

[14] Sun, Ning, et al. "Gender classification based on boosting local binary pattern." Advances in Neural Networks-ISNN 2006. Springer Berlin Heidelberg, pp 194-201, ,2006..

[15] Mu, Yadong, et al. "Discriminative local binary patterns for human detection in personal album." Computer Vision and Pattern Recognition, 2008.

[16] Takala, Valtteri, Timo Ahonen, and Matti Pietikäinen. "Block-based methods for image retrieval using local binary patterns." Image analysis. Springer Berlin Heidelberg, pp 882-891, 2005.

[17] Ojala, Timo, Matti Pietikäinen, and Topi Mäenpää. "Gray scale and rotation invariant texture classification with local binary patterns." ECCV, 2000.

[18] Qian, Xueming, et al. "PLBP: An effective local binary patterns texture descriptor with pyramid representation." Pattern Recognition 44.10, pp 2502-2515, 2011.

[19] Datar, Mayur, et al. "Locality-sensitive hashing scheme based on p-stable distributions." Proceedings of the twentieth annual symposium on Computational geometry. ACM, 2004.

[20] Rüger, Stefan. "Multimedia information retrieval." Synthesis Lectures on Information Concepts, Retrieval, and Services 1.1, pp 1-171, 2009.

[21] Box, G. E. P.; Muller, Mervin E. A Note on the Generation of Random Normal Deviates. Ann. Math. Statist. 29, no. 2, 610-611, 1958.

[22] F. Samaria and A. Harter "Parameterisation of a stochastic model for human face identification" 2nd IEEE Workshop on Applications of Computer Vision, December 1994.

[23] Markus, W. (n.d.). Face 1999 (Front). Retrieved April 11, 2016, from http://www.vision.caltech.edu/html-files/archive.html.

[24] Gary B. Huang, Manu Ramesh, Tamara Berg, and Erik Learned-Miller. “Labeled Faces in the Wild: A Database for Studying Face Recognition in Unconstrained Environments”. University of Massachusetts, Amherst, Technical Report 07-49, October, 2007.

Classifying Arabic Text Using KNN Classifier

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***Abstract*—With the tremendous amount of electronic documents available, there is a great need to classify documents automatically. Classification is the task of assigning objects (images, text documents, etc.) to one of several predefined categories. The selection of important terms is vital to classifier performance, feature set reduction techniques such as stop word removal, stemming and term threshold were used in this paper. Three term-selection techniques are used on a corpus of 1000 documents that fall in five categories. A comparison study is performed to find the effect of using full-word, stem, and the root term indexing methods. K-nearest – neighbors classifiers used in this study. The averages of all folds for Recall, Precision, Fallout, and Error-Rate were calculated. The results of the experiments carried out on the dataset show the importance of using k-fold testing since it presents the variations of averages of recall, precision, fallout, and error rate for each category over the 10-fold.**

Keywords—categorization; Arabic; KNN; stemming; cross validation

I. Introduction

Due to the advances in technology, a huge number of structured and unstructured of text documents is being published online every day. Internet users are interested in reading newspapers online, sending and reading email, participate in chat rooms and blogs, wikis, news groups, and many more. This growing amount of text on the web makes it urgent to automatically structure and categorize this text [1]. Organizations today are faced with a huge volume of information stored in digital form. Much of this information is stored in different types of documents. The increasing availability of documents in digital information has led to a huge interest in categorizing (classifying) documents (TC) [3]. As a result, computer systems are developed to automatically organize and classify documents.

In order to make use of the huge information; information needs to be managed. The end goal of information management is to locate only the relevant documents; a task which requires documents to be categorized and instead of manually classifying documents; a high precision method that performs automatic text categorization is, on the other hand, apparent.

The objective of document classification is to minimize the detail and diversity of the information by grouping similar documents together. Text classification is a process of structuring a set of documents according to a group of structure which is known in advance [1]. Another definition is "document categorization is the process of assigning a text document to one or more predefined categories (labels) based on its content" [4].

Text categorization has many applications such as document routing, document management, documents organization, text filtering, spam filtering, mails routing, word sense disambiguation, news monitoring automatic documents indexing and hierarchal catalogue of web resources. As mentioned above, text filtering is one of the applications of text categorization. Text filtering can be considered as a case of single-label TC that is categorizing of incoming documents into two disjoint categories, the relevant and the irrelevant [6, 7].

Most of the text categorization systems have been developed for English language and just few of the developed systems were for Arabic language [8]. The reason behind having fewer systems developed for Arabic Text Categorization is because of the complex nature of the Arabic Language. The focus of this study is on Arabic Text Categorization (ATC). There are several techniques and algorithms used for text classification such as: Support Vector Machine (SVM), K-nearest Neighbor (KNN), Artificial Neural Networks, Naïve Bayes classifier, and Decision Trees.

This paper is organized as follows: Section 2; describe related works in the area of automatic text categorization. Section 3 describes the Arabic language features and challenges. In section 4, the architecture of text categorization is discussed. Section 5 discusses the used classifying methodology. In section 6, experiments and results are presented. Section 7 shows the conclusions and future work.

II. Literature Review

Many machine learning algorithms have been used in text categorization, those algorithms include: decision tree learning and Bayesian learning, nearest neighbor learning, and artificial neural networks. A survey presented in [2] discusses the main approaches to text categorization.

The work of [7] showed that applying the KNN classifier using N-Grams and then by using bag of words show that using N-Grams produces better accuracy than using single terms for indexing. In a work presented in [3], a machine learning approach for classifying Arabic text documents is presented; each document was mapped by locating the N-gram frequency technique; the classification was achieved by computing a dissimilarity measure, called the Manhattan distance, between the profile of the instance to be classified and the profiles of all the instances in the training set.

The authors of [4] used three classifiers and compared their performances; the three used classifiers were naïve Bays, k-nearest-neighbors (KNN), and distance-based classifiers. Another work conducted a comparative study of two machine learning methods k nearest neighbor (KNN) and support vector machines (SVM) [9]. Full-word features was used and *tf.idf* as the weighting method for feature selection. The results showed that both methods were of high performance and that SVM showed a better micro average F1 and prediction time.

An intelligent Arabic text categorization was presented in [8], k-nearest neighbor and Rocchio classifiers were used; different term weighting schemes were used also light stemming was used as well. Their results show that Rocchio classifier performs better than k-nearest neighbor classifier. Another study conducted in [10] used stemming and light stemming techniques as feature selection techniques, K-nearest neighbors (KNN) as a classifier. Results reported indicated that light stem was superior over stemming in terms of classifier accuracy. The author of [11] proposed a distance-based classifier for categorizing Arabic text. Each category is represented as a vector of words in an m-dimensional space, and documents are categorized based on their closeness to feature vectors of categories.

III. The Arabic Language Features and Challenges

Arabic language is spoken by more than 250 million Arabic people around the world. In addition, as it is the language of the Holy Quran, Arabic language is understood by more than one billion other Muslims [12]. Arabic alphabet consists of 28 characters:

ا ب ت ث ج ح خ د ذ ر ز س ش ص ض ط ظ ع غ ف ق
ك ل م ن ه و ي

It was indicated by [13] that Arabic language poses various challenges in terms of the language stylistic properties and rules. For example, the authors of [14] show the effect of not using capital letters in Arabic words, which makes it hard to identify proper names, abbreviations and as a result it would makes it complicated in tasks such as in Information Extraction and Named Entity Recognition.

A. Arabic Characters Styles

Arabic characters have different styles when appearing in a word depending on the location of the character in the word whether it is located at the beginning, middle, or end of word and also whether the character can be connected to its neighbor characters or not. For example, the character (س) has different styles according to the location rule, (ســ) if it is located at the beginning of a word as in the word ساعة. It appears as (ـسـ) if the character appears in the middle of a word such as يسهل; (ـس) if the character appears at the end of word as in حبس. Finally, the character (س) will show as (س) if it appears at the end of a word but it will not be connected to the character to its right such as in word درس [4].

B. Arabic Diacritics

Diacritics are a property of the Arabic language; it is signals placed below or above letters in order to double the letter when it is pronounced or it acts as a short vowel. Arabic diacritics include: shada, dama, fathah, kasra, sukon, double dama, double fathah, double kasra [4]. It was noted that the absence of the diacritics can lead to a confusing and different meaning. For example, it would be impossible to distinguish between the words حُب which means love and pronounced as hubb and the word (حَب) which means seed and pronounced as habb. So, not having diacritics in most of the modern standard Arabic is considered to be a major challenge to many of Arabic Natural Language Processing (NLP) tasks [13].

C. Arabic Morphology and Word Formation

Arabic language is considered to be a highly inflected language, so it has much richer morphology than English language. For example, Arabic nouns have two genders, feminine and masculine; nouns also can be characterized as singular, dual, or plural. A noun has the nominative case when it is subject; accusative when it is the object of a verb, and the genitive when it is the object of a preposition.

In linguistics, word formation is considered to be a function of morphology. Morphological analysis of human languages is largely based on the following linguistic elements: root, stem, affixes (prefixes, infixes and suffixes), and morphemes [17]. A verb in the Arabic language can be augmented by adding prefixes, infixes and suffixes to refer to the time the event has occurred, whether the verb is plural or singular, and the sex of the participants in the verb. For example the word (أكل), which corresponds to the English verb eat, this verb can have several patterns, for example, if the prefix, characters attached at the beginning of a word, (ي) added to the verb, it becomes (يأكل) which indicates the time of the verb is in present and it is done by one male. On the other hand, if the suffix, a character attached at the end of the word, (ا) added to the verb, the verb becomes (أكلا) which indicates that the time of the event is in the past and it is done by two males.

Table I shows the different derivations for the root word kataba (كتب), its pattern, its pronunciation and the translation of the word in English to show the effect of different form of the word on the meaning [8]. Table II shows different affixes that may be added to the word معلم (Teacher) along with its meaning in English, Gender, and number [8]. Table III shows prefix particle combinations [17].

TABLE I. DIFFERENT DERIVATIONS FOR THE ROOT WORD (كتب)

Arabic Word	Pattern	Pronunciation	English Meaning
كتب	*fa'ala* (فعل)	*kataba*	*wrote*
كتابة	*fe'alah* (فِعالة)	*ketaba*	*writing*
كاتب	*fa'el* (فاعل)	*kateb*	*writter*
مكتوب	*maf'ool* (مفعول)	*maktoob*	*is writter*
كتاب	*fe'aal* (فِعال)	*ktaab*	*book*
مكتبة	*maf'alah* (مفعلة)	*maktabah*	*library*
مكتب	*maf'al* (مفعل)	*maktab*	*Office*

TABLE II. DIFFERENT AFFIXES OF TO THE WORD (معلم)

Arabic Word	English Meaning	Gender	Number
معلم	Teacher	masculine	singlular
معلمة	Teacher	feminine	singlular
معلمان	two teachers	masculine	dual
معلمون	teachers	masculine	plural (accusative, genitive)
معلمين	teachers	masculine	plural (nominative)
معلمات	teachers	feminine	plural
المعلم	the teacher	masculine	singlular
والمعلم	and the teacher	masculine	singlular
كالمعلم	as the teacher	masculine	singlular
معلمي	my teacher	masculine	singlular
معلمه	his teacher	masculine	singlular
معلمها	her teacher	masculine	singlular
معلمهم	their teacher	masculine	singlular

TABLE III. PREFIX PARTICLE COMBINATIONS

Combination	Meaning	Example
بال	in the	بالشارع (in the street)
فال	and the, therefore the	فالمدينه (therefore the city)
كال	like the	كالرئيس (like the president)
لال	for the, to the	للمجال (to the field)
وال	and the	والجامعه (and the university)
فبال	therefore in the	فبالحق (therefore in the right)
وبال	and in the	وبالوسط (and in the center)
وكال	and like the	وكالشمس (and like the sun)
ولال	and for the	ولليسار (and for the left)
فب	and in, therefore in	فبنوم (therefore in sleep)
وب	and in	وبحركه (and in movement)
فل	and for, therefore to	فلمعركه (and for battle)
ول	and for, and to	ولزمان (and to time)

IV. ARCHITECTURE OF TEXT CATEGORIZATION

The text categorization (TC) process consists of three key components: data pre-processing, classifier construction, and document categorization, as shown in Figure 1. Data pre-processing implements the function of transferring the original document into a compact representation and will be uniformly applied to training, validation, and classification phases. Classifier construction does inductive learning from a training set of documents, and document categorization process is document classification. In Fig. 1, the arrow with dashed line represents the data flow in the categorization process and the arrow with the solid line represents the data flow in the classifier construction process.

A. Data Pre-Processing

Text documents consist of words made of characters, digits, and special symbols. The pre-processing phase focuses on extracting the words which best describing the document and eliminate the others. This all can be done through many steps such as normalization, dimensionality reduction, and feature creation [15].

B. Normalization

Normalization is the process of finding the standard form for all words found in the documents of the corpus [11]. The normalization process consists of the following steps:

1) Punctuation marks removal

2) Stop words removal, stop words are useless words; stop words include: prepositions, definition articles, and conjunctions.

3) Non-letters removal

4) Diacritics removal

5) Replace initial إ or أ with bare alif ا, replace آ with ا, replace the sequence ىء with ئ, replace final ى with ي, and replace final ة with ه

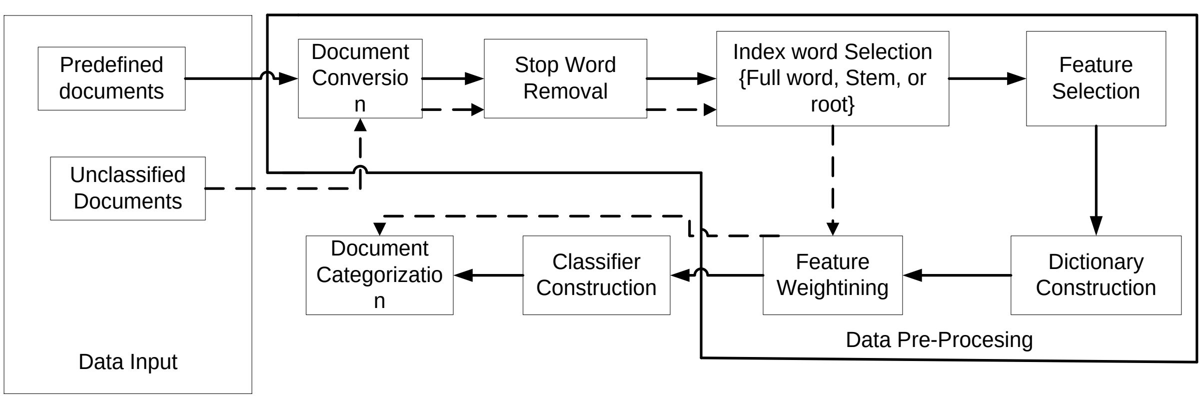

Fig. 1. The architecture of text categorization

C. Feature Selection and Reduction

A text document can have a large number of features (words). Imagine the case where you have thousands of text documents and each document is represented by a vector; vector entries are the frequencies with which each word occurs in the document. There are many gains to dimensionality reduction [15]:

1) Many data mining algorithms perform better if the dimensionality – the number of attributes in the document is lower; the reason for this benefit is that because the dimensionality reduction can eliminate unsuitable features.

2) Dimensionality reduction can lead to a more understandable model because the model may involve fewer attributes.

3) Dimensionality reduction will facilitate data visualization.

The following are two techniques for feature set reduction:

1) Feature Selection. Document vector dimensionality can be reduced by selecting just a subset of original features. The objective of this phase is to eliminate the features (words), which can be considered to be less important information about the document .There are many ways to feature selection. Removing stop words as mentioned before is one way to eliminate unimportant features [1]. Computing term-goodness based on the statistical characteristics of the dataset such as document frequency, information gain, and mutual information is another way [10]. A threshold method, as a method of feature selection is based on removing some features, the removal will be based on the frequencies of those features by setting that frequencies be greater than or less than a defined threshold value. Examples of threshold methods are: document frequency thresholding and chi-square.

In information theory methods, the least predictable terms carry the greatest information value. The least predictable terms are those that exist with the smallest probabilities. Information theory concepts have been used to derive a measure called signal-noise ratio, of term usefulness for indexing (need re-phrasing) [16].

2) Heuristic based selection techniques. Other feature selection techniques uses heuristic information to calculate the similarity and relations that can exist between the features in a text document , stemming techniques that extracts the word's roots, and domain ontology that is based on semantic relations between the features are two examples of heuristic techniques. There are indicators to the importance of features in a document such as term frequency (TF), inverse document frequency (IDF), and their multiplicative combination (TF×IDF) [1].

In the linguistic approach, it simulates the behavior of a linguist by considering Arabic morphological system and analyzing Arabic words according to their morphological components. In this approach, prefix and suffix of a given word are removed by comparing the leading and trailing characters with a given list of affixes in table.

D. Stemming

Stemming is any process to strip additives from the word, In English and English like languages stemming is the process of stripping suffixes from word, however Arabic language words may have additives anywhere in the word and not only suffixes which complicates the stemming task, to ease the process of stemming many researchers introduced light stemming for Arabic language which concentrated on removing all or subset of the affixes (prefixes and suffixes) without touching the additives in the middle of the word (infixes).

Statistical stemmers did not work well for Arabic language while for English and English like languages achieved great results. On the other hand, morphological approaches generate the Arabic word root or set of possible roots. Recently Shawakfa et al. [12] conducted a research that compare different approaches of root finding but most of these approaches generate incorrect root. In the combinational approach, the word to be stemmed is used to generate all possible combinations of letters. Those combinations are matched against predefined lists of Arabic roots. If there is a match, stem and patterns are extracted [18].

Arabic stemming algorithms can be classified as: stem-based, root-based algorithms. Stem–base algorithms basically work by removing all prefixes and suffixes from Arabic words, while on the other hand the root-based algorithms work by reducing stems to roots. Light stemming is the process of stripping off a small set of prefixes and/or suffixes without trying to deal with infixes or recognize patterns and find roots.

Stemming reduces the number of features in a document. Stemming is a computational process that collects all words which share the same stem and have the some semantic relation [14]. The goal of the stemming process is to remove all possible affixes, so as a result reducing the word to its stem. Stemming is usually used for document matching and categorization by finding the standard form of a word in a document and select as a representative for all words of that standard form. There exist many stemming techniques: table lookup, linguistic, and combinational techniques. In table lookup approach, there is a list which consists of all valid Arabic words along with their morphological decompositions. Simply, for a given word it accesses the list and retrieves the associated root/stem. In this case the resulted stem is guaranteed to be accurate. But the backward with this technique is that it is not possible to build a table that has all language words.

V. Used Classifying Methodology

The goal of document categorization is to assign documents to a pre-defined and fixed set of documents [1]. Document categorization involves the process of automatically learning categorization patterns so that the categorizations of new documents will be trivial. Categorization models can be divided into three types: the first type identified by "older models" which consists of Boolean and vector space models. The second type is identified by "probabilistic models" which consists of BM25 and language models. The third type is identified by "combining evidence models" which consists of inference networks and learning to rank models [20].

Nearest Neighbor learners are considered to be lazy learners as they delay the process of modeling the training data until a new document is classified. Rote classifier is an example of a lazy learner, which memorizes the entire training data and does classification only if the features (attributes) of a test document match one of the training documents exactly.

Nearest-neighbor classification technique is part of the instance-based learning technique, which basically uses training documents to make predictions for tested documents without having a model derived from data. Instance-based learning techniques require a proximity measure to determine the similarity between the training documents and the classification function which returns the predicted class of the document under testing based on its proximity to other training documents [15].

KNN classifier is chosen to implement the system for the following reasons: it's simple, similarity measure is reasonable, and doesn't need any resources for training despite some disadvantages such as the above-average categorization time because there was no time invested in the learning phase [1].

The focus of this study is on Vector Space Model (VSM). In VSM, both training documents and tested documents are represented as vectors. Each term in a document is given a weight; the weight indicates the importance of the term in both the document and within the documents in the whole collection of documents.

In this context, q refers to a tested document. A document D_i in the collection of documents and a tested document q can both be represented as vectors, $D_i = (d_{i1}, d_{i2}, \ldots, d_{it})$ and $q = (q_1, q_2, \ldots, q_t)$, where t is the number of index terms in the collection, each d_{ij} and q_j represents document term and tested document term weights respectively.

A. Term Weighting

There are many approaches for term weighting. In this work, a well-known approach called *tf*idf* is used, which is given by equation (1) [21].

$$w_{i,j} = tf_{i,j} * idf_j = tf_{i,j} * \log_{10}(N/df_j) \quad (1)$$

Where $w_{i,j}$ is the weight of term j in document i, $tf_{i,j}$ is the number of times a term j occurs in a document i, idf_j is the number of documents in which the term j appears, and N is the total number of documents in the collection.

Since documents in the collection of text documents does not have the same length (i.e., number of features in documents are not the same), short documents might not have the same chance to be recognized as relevant as long documents; because of this, the retrieval of any document must be made independent of its length; this can be done by normalizing document vectors. So, this makes it fair to retrieve documents of all different lengths. The $tf_{i,j}$ (the raw frequency) is normalized by dividing the raw frequency of the term by the raw frequency of the most common term in the document ($tf_{i,j}/\max(tf_{i,j})$). So, the new term weight is represented by equation (2).

$$w_{i,j} = (tf_{i,j}/\max(tf_{i,j})) * \log_{10}(N/df_j) \quad (2)$$

This way, terms' weights are restricted to be between zero and one; higher weight approach one indicates that the term is important whereas weight approaches zero indicates less important term [22].

B. Similarity Measures

Once the weights for terms in all documents in the collection of text documents are computed, a ranking function is needed to measure the similarity between training document vectors and tested documents. There exist many ranking functions such as Cosine similarity, Euclidean distance, Dice coefficient, Jaccard measure, and Manhattan distance. In this work, cosine measure is used [21]. Cosine measure is one of the most frequently used similarity measures; it calculates the cosine of the angle between the vector of the document and the vector of a tested document. The cosine measure is computed by equation (3).

$$\text{Cos-Sim}(D_i, q) = \frac{\vec{D_i} \bullet \vec{q}}{\left|\vec{D_i}\right| \times \left|\vec{q}\right|} = \frac{\sum_{j=1}^{t} d_{ij} \times q_j}{\sqrt{\sum_{j=1}^{t} d_{ij}^2} \times \sqrt{\sum_{j=1}^{t} q_j^2}} \quad (3)$$

Where vector D_i represent a training document Di and vector q represents a tested document q. After similarity calculation, documents are then ranked by decreasing cosine value.

C. Evaluation Measurements

The effectiveness of Text Categorization techniques is measured using IR evaluation metrics, such as Recall, Precision, Fallout, Error rate and F measure [11]. Recall is defined as the percentage of relevant documents retrieved out of all the relevant documents in the collection whereas precision is defined as the percentage of relevant documents retrieved out of all retrieved documents. The F-measure is the harmonic mean of the recall and precision.

Assume the case of a binary classification problem where there is only one category and n documents to be classified, then any of the n documents might or might not belong to that category; a document is considered a positive example if it belongs to that category and a negative example in case that document does not belong to that category. So, the documents that have already been classified (given a category) were classified by human experts (Human classifier), beside a computer program will categorize those categorized documents. So, the comparison between human classifier and the program classifier is done by means of recall, precision, fallout, error rate, and F-measure. Those measures are shown in Table IV [5].

TABLE IV. COMMON PERFORMANCE MEASURES

Performance measure	Definition
Recall	$R_i = a_i / (a_i + c_i)$
Precision	$P_i = a_i / (a_i + b_i)$
Fallout	$F_i = b_i / (b_i + d_i)$
Error rate	$Err_i = (b_i + c_i) / (a_i + b_i + c_i + d_i)$
F-measure	$Fm_i = (2 * R_i * P_i) / (R_i + P_i)$

Where a_i is the number of documents correctly assigned to category i, b_i is the number of documents incorrectly assigned to category i, c_i is the number of documents correctly rejected from category i, and d_i is the number of documents incorrectly rejected from category i.

D. Dataset Used

The proposed approach is tested using 1000 normalized documents collected from different digital Arabic newspapers. The 1000 documents are equally distributed over five categories: Arts, Politics, Science, Economics, and Sports. In this work three types of word indexing are used: full-word, root, and stem; the stem is obtained by removing prefixes and suffixes from Arabic words (features). In this work, the stemmer proposed by [19] is used. Table V shows the statistics of the Arabic text collection.

TABLE V. ARABIC TEXT COLLECTION STATISTICS

Number of documents	1,000		
Number of words in the collection (excluding stop-words)	204,818		
Type of index-term	***Full-word***	***Stem***	***Root***
Collection size	1.35 MB	1 MB	990 KB
Number of distinct words in the collection (excluding stop-words)	39,819	12,502	13,113

The proposed system is tested for each indexing type using 10-fold cross validation. In every fold, the same number of documents from each category is chosen as tested documents and the remaining are used as training documents, so each document will have the chance to be included in the test collection.

E. Cross-Validation

In this approach, a document is used the same number of times for training and just once for testing. Here the documents are divided into two subsets: one subset for training and the other for testing. Then the role of the two subsets is swapped so that the previous test subset becomes training and the other training subset becomes testing subset. In this work, the corpus is partitioned to be 9/10 as training subset and 1/10 as test subset. Also k-fold cross-validation method is used in which during each run, one of the partitions is selected for testing. While the rest of the documents used for training. This approach is repeated k times so that each partition is used for testing exactly once. In this work, 10-fold cross-validation is used.

F. Classifier Construction

The following are the steps used to build the classifier:

a) Building the index of all documents in the collection. This step involves grouping terms in each document by finding the count of each term in each document.

b) Find the number of documents where each term occur.

c) Find the weight of each term according to the following formula:

d) $w_{ij} = f_{ij}*\lg(N/n_i)$ where f_{ij} is the number of times a term occur in a document, n_i is the number of documents a term occur, and N is the number of documents in the collection.

e) Join the training documents with tested documents based on common terms.

f) Build cosine similarity measure using equation:

The nearest K neighbors among all training documents are determined as a result of calculation. Those K neighbors may be of different categories so the document will be assigned to the category that has the maximum number of documents included in the K nearest neighbors. The similarity measure used in this work is Cosine similarity measure and the value of K used is 80.

VI. EXPERIMENTS AND RESULTS

Table VI shows recall, precision, fallout, and error rate over 10-folds for each category. Also the table shows that recall reaches its highest (0.98) for art category, and the lowest value (0.85) for the politics category. On the other hand, precision reaches its highest for sport (0.99), and the lowest is (0.87) for art. Table VII shows recall, precision, fallout, and error rate over 10-folds for each category. Also the table shows that recall reaches its highest (0.99) for sport category, and the lowest value (0.86) for the politics category. On the other hand, precision reaches its highest for sport (1), and the lowest is (0.90) for economics. Table VIII shows recall, precision, fallout, and error rate over 10-folds for each category. Also the table shows that recall reaches its highest (0.98) for sport category, and the lowest value (0.88) for the politics category. On the other hand, precision reaches its highest for sport (0.99), and the lowest is (0.92) for economics.

After looking at Tables VI, VII, and VIII, one can conclude that politics showed to have minimum recall for full-word, root, and stem indexing whereas sport showed maximum precision for full-word, root, and stem indexing.

Table IX shows the min, max, average for 10-folds for each one of the five categories where 9/10–1/10 ratio used for training/test ratio and using full-word term indexing. Table X shows the min, max, average for 10-folds for each one of the five categories where 9/10–1/10 ratio used for training/test ratio and using root term indexing. Table XI shows the min, max, average for 10-folds for each one of the five categories where 9/10–1/10 ratio used for training/test ratio and using stem term indexing.

Figures 2, 3, 4, 5, 6, and 7 show the usefulness of using cross-validation where document will have the chance to be chosen to a tested document. The figures show the variations of averages of recall and precision for each category spanning over 10-folds using full-word, stem, and root indexing.

TABLE VI. RECALL, PRECISION, FALLOUT, AND ERROR RATE OVER 10-FOLDS FOR EACH CATEGORY USING FULL-WORD INDEXING

Category	Recall	Precision	Fall Out	Error Rate
Art	0.9892	0.8750	0.0025	0.0270
Economic	0.9496	0.9400	0.0125	0.0220
Politics	0.8587	0.9450	0.0413	0.0440
Science	0.9729	0.9700	0.0075	0.0120
Sport	0.9772	0.9900	0.0063	0.0070

TABLE VII. RECALL, PRECISION, FALLOUT, AND ERROR RATE OVER 10-FOLDS FOR EACH CATEGORY USING ROOT INDEXING

Category	Recall	Precision	Fall Out	Error Rate
Art	0.9657	0.9150	0.0088	0.0240
Economic	0.9565	0.9050	0.0100	0.0270
Politics	0.8621	0.9300	0.0413	0.0470
Science	0.9729	0.9750	0.0075	0.0110
Sport	0.9952	1.0000	0.0012	0.0010

TABLE VIII. RECALL, PRECISION, FALLOUT, AND ERROR RATE OVER 10-FOLDS FOR EACH CATEGORY USING STEM INDEXING

Category	Recall	Precision	Fall Out	Error Rate
Art	0.9712	0.9300	0.0075	0.0200
Economic	0.9398	0.9250	0.0150	0.0270
Politics	0.8823	0.9269	0.0325	0.0409
Science	0.9577	0.9700	0.0113	0.0150
Sport	0.9861	0.9900	0.0038	0.0050

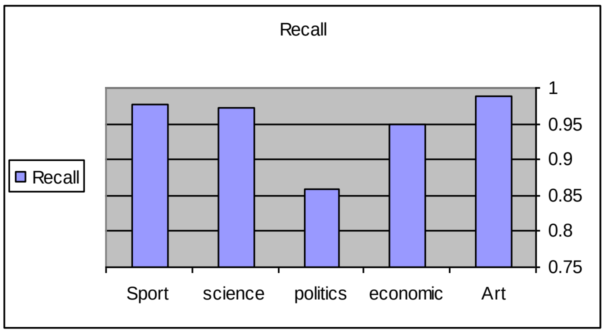

Fig. 2. Variations of average of recall over 10-folds for each category using full-word indexing

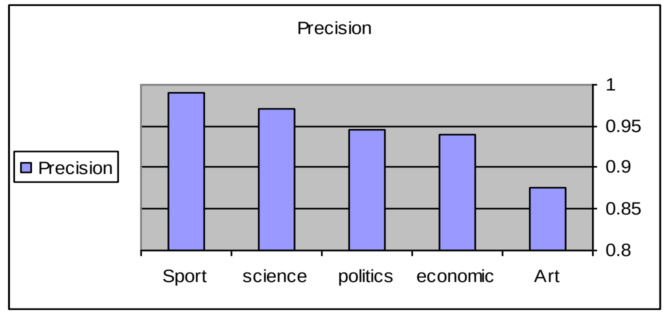

Fig. 3. Variations of average of precision over 10-folds for each category using full-word indexing

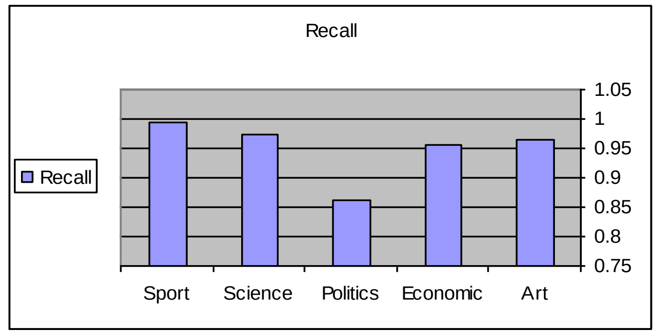

Fig. 4. Variations of average of recall over 10-folds for each category using root indexing

TABLE IX. MAX, MIN, AND AVERAGE FOR 10-FOLD USING FULL-WORD FOR ALL CATEGORIES

Category	Iteration No.	Recall	Precision	Category	Iteration No.	Recall	Precision
Art	1	1.0000	0.7500	Economic	1	0.9474	0.9000
Art	2	1.0000	0.9500	Economic	2	0.9524	1.0000
Art	3	0.9444	0.8500	Economic	3	0.9444	0.8500
Art	4	1.0000	0.7500	Economic	4	0.9524	1.0000
Art	5	1.0000	0.9000	Economic	5	1.0000	1.0000
Art	6	1.0000	0.9000	Economic	6	1.0000	1.0000
Art	7	1.0000	0.8500	Economic	7	1.0000	1.0000
Art	8	1.0000	0.9000	Economic	8	0.8889	0.8000
Art	9	0.9474	0.9000	Economic	9	0.8636	0.9500
Art	10	1.0000	1.0000	Economic	10	0.9474	0.9000
Maximum		***1.0000***	***1.0000***	***Maximum***		***1.0000***	***1.0000***
Minimum		***0.9444***	***0.7500***	***Minimum***		***0.8636***	***0.8000***
Average		***0.9892***	***0.8750***	***Average***		***0.9496***	***0.9400***
Politics	1	0.7692	1.0000	Science	1	1.0000	1.0000
Politics	2	0.9500	0.9500	Science	2	1.0000	0.8500
Politics	3	0.7600	0.9500	Science	3	1.0000	1.0000
Politics	4	0.7917	0.9500	Science	4	1.0000	1.0000
Politics	5	0.9091	1.0000	Science	5	1.0000	1.0000
Politics	6	0.9524	1.0000	Science	6	1.0000	1.0000
Politics	7	0.9000	0.9000	Science	7	0.8696	1.0000
Politics	8	0.7500	0.9000	Science	8	0.9500	0.9500
Politics	9	0.8571	0.9000	Science	9	1.0000	0.9000
Politics	10	0.9474	0.9000	Science	10	0.9091	1.0000
Maximum		***0.9524***	***1.0000***	***Maximum***		***1.0000***	***1.0000***
Minimum		***0.7500***	***0.9000***	***Minimum***		***0.8696***	***0.8500***
Average		***0.8587***	***0.9450***	***Average***		***0.9729***	***0.9700***
Sport	1	1.0000	1.0000				
Sport	2	0.8696	1.0000				

Sport	3	1.0000	0.9500				
Sport	4	1.0000	1.0000				
Sport	5	1.0000	1.0000				
Sport	6	0.9524	1.0000				
Sport	7	1.0000	1.0000				
Sport	8	1.0000	1.0000				
Sport	9	0.9500	0.9500				
Sport	10	1.0000	1.0000				
Maximum		***1.0000***	***1.0000***				
Minimum		***0.8696***	***0.9500***				
Average		***0.9772***	***0.9900***				

TABLE X. MAX, MIN, AND AVERAGE FOR 10-FOLD USING ROOT FOR ALL CATEGORIES

Category	**Iteration No.**	**Recall**	**Precision**	**Category**	**Iteration No.**	**Recall**	**Precision**
Art	1	1	0.7	Economic	1	0.882353	0.75
Art	2	1	0.95	Economic	2	0.95	0.95
Art	3	1	0.95	Economic	3	0.947368	0.9
Art	4	0.947368	0.9	Economic	4	0.952381	1
Art	5	0.95	0.95	Economic	5	1	1
Art	6	0.857143	0.9	Economic	6	1	1
Art	7	1	0.85	Economic	7	1	1
Art	8	0.95	0.95	Economic	8	0.928571	0.65
Art	9	0.952381	1	Economic	9	0.904762	0.95
Art	10	1	1	Economic	10	1	0.85
Maximum		***1***	***1***	***Maximum***		***1***	***1***
Minimum		***0.857143***	***0.7***	***Minimum***		***0.882353***	***0.65***
Average		***0.965689***	***0.915***	***Average***		***0.956544***	***0.905***
Politics	1	0.655172	0.95	Science	1	1	1
Politics	2	0.904762	0.95	Science	2	1	0.95
Politics	3	0.869565	1	Science	3	1	0.95
Politics	4	0.9	0.9	Science	4	1	1
Politics	5	0.95	0.95	Science	5	1	1
Politics	6	0.894737	0.85	Science	6	1	1
Politics	7	0.9	0.9	Science	7	0.869565	1
Politics	8	0.692308	0.9	Science	8	0.95	0.95
Politics	9	0.95	0.95	Science	9	1	0.9
Politics	10	0.904762	0.95	Science	10	0.909091	1
Maximum		***0.95***	***1***	***Maximum***		***1***	***1***
Minimum		***0.655172***	***0.85***	***Minimum***		***0.869565***	***0.9***
Average		***0.862131***	***0.93***	***Average***		***0.972866***	***0.975***
Sport	1	1	1				
Sport	2	0.952381	1				
Sport	3	1	1				
Sport	4	1	1				
Sport	5	1	1				
Sport	6	1	1				
Sport	7	1	1				
Sport	8	1	1				
Sport	9	1	1				
Sport	10	1	1				
Maximum		***1***	***1***				
Minimum		***0.952381***	***1***				
Average		***0.995238***	***1***				

TABLE XI. MAX, MIN, AND AVERAGE FOR 10-FOLD USING STEM FOR ALL CATEGORIES

Category	**Iteration No.**	**Recall**	**Precision**	**Category**	**Iteration No.**	**Recall**	**Precision**
Art	1	1	0.8	Economic	1	0.9	0.9
Art	2	1	0.95	Economic	2	0.95	0.95
Art	3	0.95	0.95	Economic	3	0.9	0.9
Art	4	1	0.85	Economic	4	0.95	0.95
Art	5	0.904762	0.95	Economic	5	1	0.95
Art	6	0.904762	0.95	Economic	6	0.952381	1
Art	7	1	0.95	Economic	7	1	1

Art	8	1	0.9	Economic	8	0.941176	0.8
Art	9	0.952381	1	Economic	9	0.857143	0.9
Art	10	1	1	Economic	10	0.947368	0.9
Maximum		***1***	***1***	***Maximum***		***1***	***1***
Minimum		***0.904762***	***0.8***	***Minimum***		***0.857143***	***0.8***
Average		***0.97119***	***0.93***	***Average***		***0.939807***	***0.925***
Politics	1	0.772727	0.894737	Science	1	0.909091	1
Politics	2	0.904762	0.95	Science	2	1	0.9
Politics	3	0.863636	0.904762	Science	3	1	0.95
Politics	4	0.826087	0.95	Science	4	1	1
Politics	5	0.9	0.947368	Science	5	0.952381	1
Politics	6	0.944444	1	Science	6	1	1
Politics	7	0.947368	1	Science	7	0.909091	1
Politics	8	0.72	0.818182	Science	8	0.95	0.95
Politics	9	0.944444	0.894737	Science	9	0.947368	0.9
Politics	10	1	0.909091	Science	10	0.909091	1
Maximum		***1***	***1***	***Maximum***		***1***	***1***
Minimum		***0.72***	***0.818182***	***Minimum***		***0.909091***	***0.9***
Average		***0.882347***	***0.926888***	***Average***		***0.957702***	***0.97***
Sport	1	1	1				
Sport	2	0.909091	1				
Sport	3	1	0.95				
Sport	4	1	1				
Sport	5	1	0.95				
Sport	6	1	1				
Sport	7	1	1				
Sport	8	1	1				
Sport	9	0.952381	1				
Sport	10	1	1				
Maximum		***1***	***1***				
Minimum		***0.909091***	***0.95***				
Average		***0.986147***	***0.99***				

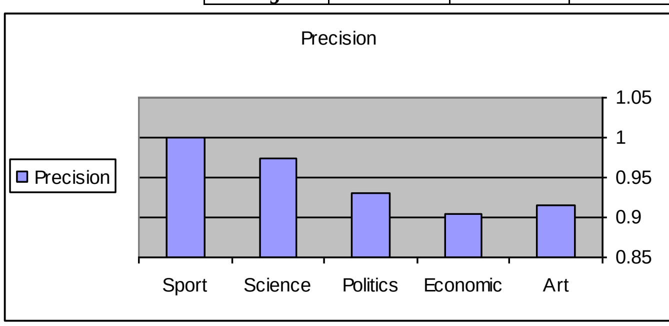

Fig. 5. Variations of average of precision over 10-folds for each category using root indexing

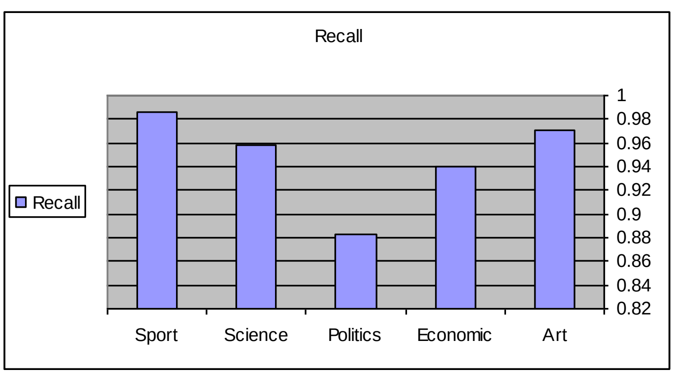

Fig. 6. Variations of average of recall over 10-folds for each category using stem indexing

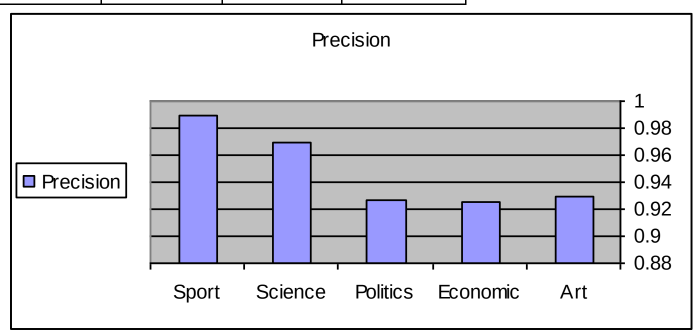

Fig. 7. Variations of average of precision over 10-folds for each category using stem indexing

VII. Conclusion and Future Work

This paper has presented a KNN classifier for Arabic text categorization. Since Arabic language has rich morphology, processing Arabic text was not a trivial task; as we have seen that a single word can have many formations and also a letter in a word can have many styles depends on the location where the letter occur in a word. The classifier is tested against 1000 documents consists of five categories. Vector space model is used to model data. Stop word removal and document frequency threshold methods used for feature selection and reduction. Full-word, stem, and root used for term indexing. In future, we are looking for using the concept of ontology's for enhancing the classifier performance.

REFERENCES

[1] H. Brucher, G. Knolmayer, and M. A. Mittermayer, “Document classification methods for organizing explicit knowledge,” in Organizational Knowledge, Learning, and Capabilities, Athens, Greece, 2002, pp. 1-26.

[2] F. Sebastiani , “Machine learning in automated text categorization,” ACM Computing Surveys, vol. 34(1), 2002.

[3] L. Khreisat, “A machine learning approach for Arabic text classification using N-gram frequency statistics,” Journal of Informetrics, vol. 3(1), pp. 72-77, 2009.

[4] R. Duwairi, “Arabic Text Categorization,” The International Arab Journal of Information Technology, vol. 4(2), 2007.

[5] A. Al-Badarneh, E. Al-Shawaka, B. Bani-Ismail, K. Al-Rababah, and S. Shatnawi, “The impact of indexing approaches on Arabic text classification,” Journal of Information Science, in press.

[6] G. Guo, H. Wang, D. Bell, Y. Bi, and K. Greer, “An KNN Model-based Approach and Its Application in Text Categorization,” in Computational Linguistics and Intelligent Text Processing, 2004, pp. 559-570.

[7] R. Al-Shalabi and R. Obeidat, “Improving KNN Arabic Text Classification with N-Grams Based Document Indexing,” in Informatics and Systems, 2008, pp. 108-112.

[8] M. Syiam, Z. Fayed, and M. Habib, “An intelligent system for Arabic text categorization,” Int. Journal of Intelligent Computing and Information Sciences, vol. 6(1), pp. 1-19, 2006.

[9] I. Hmeidi, B. Hawashin, and E. El-Qawasmeh, “Performance of KNN and SVM classifiers on full word Arabic articles”, Advanced Engineering Informatics, vol. 22(1), pp. 106-111, 2008.

[10] R. Duwairi, M. Al-Refai, and N. Khasamneh, “Stemming Versus Light Stemming as Feature Selection Techniques for Arabic Text Categorization,” in Innovations in Information Technology, 2007, pp. 446-450.

[11] R. Duwairi, “Machine learning for Arabic Text Categorization,” Journal of the American society for information science and technology, vol. 57(8), pp. 1005-1010, 2006.

[12] E. Al-Shawaka, A. Al-Badarneh, S. Shatnawi, K. Al-Rababah, and B. Bani-Ismail, “A comparison Study of Some Arabic Root Finding Algorithms”, Journal of the American society for information science and technology, vol. 61(5), pp. 1005-1010, 2010.

[13] N. Abouzakhar, B. Allison, and L. Guthrie “Unsupervised Learning-based Anomalous Arabic Text Detection,” in Language Resources and Evaluation, 2008, pp. 291-296.

[14] R. Al-Shalabi et al., “Proper Noun Extracting Algorithm for Arabic Language,” in IT to Celebrate S. Charmonman’s 72nd Birthday, 2009.

[15] P. Tan, M. Steinbach, and V. Kumar, Introduction to Data Mining, Addison-Wesley, USA, 2005.

[16] K. Fuka and R. Hanka, “Feature set reduction for document classification problems,” in Artificial Intelligence, 2001, pp. 1-7.

[17] H. Moukdad, “Stemming and root-based approaches to the retrieval of Arabic documents on the Web,” Webology, vol. 3(1), 2006.

[18] H. Al-Sherhan and A. Ayesh, “A triliteral Word Roots Extraction Using Neural Network for Arabic,” in Computer Engineering and Systems, 2006, pp. 436-440.

[19] S. Ghwanmeh, G. Kanaan, R. Al-Shalabi, and S. Rabab'ah, “Enhanced algorithm for extracting the root of Arabic words,” in Computer Graphics, Imaging and Visualization: New Advances and Trends, 2009, pp. 388-391.

[20] B. Croft, D. Metzler, and T. Strohman, Search engines: information retrieval in practice, Addison-Wesley, USA, 2009.

[21] D. Lee, H. Chuang, and K. Seamons, “Document ranking and the vector-space model,” IEEE Software, vol. 14(2), pp. 67-75, 1997.

[22] F. Harrag, A. Hamdi-Cherif, and E. El-Qawasmeh, “Vector space model for Arabic information retrieval–application to hadith indexing,” in the Applications of Digital Information and Web Technologies, 2008, pp. 107-112.

Knowledge Extraction from Metacognitive Reading Strategies Data Using Induction Trees

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***Abstract*—The assessment of students' metacognitive knowledge and skills about reading is critical in determining their ability to read academic texts and do so with comprehension. In this paper, we used induction trees to extract metacognitive knowledge about reading from a reading strategies dataset obtained from a group of 1636 undergraduate college students. Using a C4.5 algorithm, we constructed decision trees, which helped us classify participants into three groups based on their metacognitive strategy awareness levels consisting of global, problem-solving and support reading strategies. We extracted rules from these decision trees, and in order to evaluate accuracy of the extracted rules, we built a fuzzy inference system (FIS) with the extracted rules as a rule base and classified the test dataset with the FIS. The extracted rules are evaluated using measures such as the overall efficiency and Kappa coefficient.**

Keywords—Metacognitive Reading Strategies; Classification; Induction Tree; Rule Extraction; Fuzzy Inference System

I. Introduction

A student in any field has many ways of learning and being taught. In order to improve these methods, it is important to understand students' levels of metacognitive knowledge and skills. Metacognition, briefly defined as the awareness and understanding of one's thought processes, is fundamental in developing effective reading comprehension and problem solving skills and strategies. These skills show how well students are able to solve complex tasks such as reading comprehension. There is agreement among researchers that variability in reader characteristics can be used to partially explain individual differences in reading comprehension performance [1]. The process of reading is greatly influenced by the beliefs, attitudes, and values that readers possess. We know, for instance, that how students feel and know about their own cognitive and metacognitive abilities and skills affects whether they succeed or fail in school. Indeed, the development of metacognitive beliefs about reading and the understanding of the parameters and complexities involved in reading tend to develop whenever and wherever students receive instruction in reading.

Various methods have been used to gather data on metacognitive awareness. In order for the data to be useful, knowledge must be extracted from a dataset. Knowledge discovery in databases (KDD) is the process of analyzing data to find patterns and useful information that can be used to gain knowledge from the data. Data mining is a step in the KDD process, where rules and patterns can be extracted from data for a given purpose. Data mining involves classification, regression, clustering, and rule generation among many things [2]. Selecting a method to evaluate a dataset depends largely on the type of data to be processed. Using these methods, information can be extracted in the form of rules. A rule states how different attributes are correlated with one another in a dataset. There are several different methods that can be used to extract rules. These include the black-box method, link tracing in neural networks, decision trees, and association rules. In a black-box method the system receives inputs and produces outputs without revealing to the user the complex workings of the algorithm or requiring them to have some knowledge of how to operate it. This can prove a benefit for many fields of work where specific calculations need to be performed on large, complex datasets. Malone et al. [3] have used Kohonen network for data mining and have used Kohonen feature maps to formulate rules. Fung et al. [4] used Support Vector Machines (SVM) to extract rules from datasets by expressing the variable space as hyper-cubes. Ali et al. [5] have shown it is possible to extract useful rules using decision tree induction by suggesting improvements to the existing C4.5 decision tree algorithm. Zhou et al. [6] have shown that neural networks are able to extract rules from datasets by creating ensembles of multiple neural networks that can work together to classify data.

Anderson et al. [7] have used neural networks to identify students' levels of metacognitive awareness using data collected via the Metacognitive Awareness of Reading Strategies Inventory (MARSI). In this work we have used an induction tree to analyze a new MARSI dataset. The main advantage of induction trees is that an induction tree is able to take data from the instrument with little or no modification and process it resulting in clear, simplified rules that do not require a special knowledge or other skill to understand. A fuzzy inference system (FIS) can be built with the extracted rules as a rule-base. The FIS can further enhance the understanding of the study by providing additional information relating to how the different sets of relationships interact with each other. The FIS has been used widely in the medical field to study ailments such as cancer [8], preventing heart attacks [9] and classification of heart data [10]. It has also been applied to other fields, such as image steganography, the process of hiding information in images [11], and gas and oil consumption [12]. The FIS has proven to be a useful tool that is able to classify unknown data quickly where it is impractical to use human experts. In this research work, we seek to uncover relationships among student variables such as perceptions of self as a reader in relation to their levels of metacognitive strategy awareness and perceived use of reading strategies using an ID3 induction tree. Four different induction trees were built using four sets of features. Randomly selected half samples were used to construct the induction trees and remaining half samples were classified to evaluate accuracy of classification. Classification rules in the form of knowledge were extracted from the trees. In order to validate each set of the extracted rules, we built a Fuzzy Inference System (FIS) with the extracted rule as rule base and reclassified test samples. Section 2 describes the methodology used that is the induction tree and the FIS. Section 3 deals with results and discussions, and Section 4 provides conclusions.

II. Method

We applied C4.5 induction trees to extract rules from a dataset consisting of results from an instrument distributed to undergraduate college students to assess their metacognitive awareness and use of reading strategies. These rules were then tested for accuracy using a fuzzy inference system. The purpose was to extract students' metacognitive knowledge about reading using a metacognitive awareness strategies inventory. Specifically, we wanted to identify relationships between categories to better understand how different reading strategies relate to each other and affect overall reading skills. This information will be valuable in helping students understand their metacognitive awareness and creating teaching and learning programs designed to improve on these skills.

A. MARSI Dataset

In this study, we used a set of reading strategies data using the Metacognitive Awareness of Reading Strategies Inventory [13], which was administered to a group of college freshmen and sophomores enrolled in a community college in the south central US. The original dataset had 1811 records, which were pruned down to 1636 to accommodate missing or incomplete data. It is worth noting that the sample size is sufficient in light of the main objective of the study, which is to extract students' metacognitive knowledge about reading using a metacognitive awareness of reading strategies inventory. The size of the data set used is also consistent with similar data sets used in prior studies exploring students' metacognitive knowledge about reading [14]. The instrument consists of thirty questions designed to assess students' level of awareness or perceived use of reading strategies by classifying the questions into different categories. The questions assess what kind of reading strategies a student uses while reading conventional academic texts. Depending on the responses, ranging from 'never or almost never' to 'always or almost always', the students can be placed in three different reading categories and in a combined overall category. These categories cover three broad areas of strategies including (a) Global Reading Strategies (GLOB), which can be thought of as reading strategies used when preparing to read text (e.g., setting purpose for reading, previewing text content, predicting what the text is about); (b) Problem-Solving Strategies (PROB) which are typically used during reading when problems develop in understanding textual information (e.g., checking one's understanding upon encountering conflicting information, re-reading for better understanding); and (c) Support Reading Strategies (SUP), which scaffold or support the process of reading and text understanding (e.g., use of reference materials like dictionaries and other support systems). These three categories of reading strategies contribute to a calculation of a student's overall reading strategy score. Using the scores of these categories, a student can be classified into a 'Low', 'Medium', or 'High' category with respect to their levels of reading strategy awareness and perceived use of reading strategies when reading academic texts.

B. Data Analysis

We used C4.5 induction tree, a variation of the ID3 induction tree, to analyze the datasets. Both the ID3 and C4.5 induction trees were proposed by Quinlan [15]. ID3 and C4.5 are very similar methods, but have a few differences. For example, the C4.5 algorithm allows the usage of both continuous and discrete attributes, whereas the ID3 algorithm has difficulty dealing with continuous data since it is more intensive to find a proper split on this kind of attribute [16]. Tree classifiers use supervised learning methods to organize data results into a hierarchical tree, with each node correlating to a different attribute. The possible values of each attribute become the branches that lead to child nodes. Each node acts as a separate decision, and leads to a class at bottom of the tree, or the leaves. These trees act as multi-stage classifiers and are more efficient than single-stage classifiers since decisions are made at multiple levels and reduce the computational load [17]. By selecting a leaf node and traversing up the tree recording attributes and decision values until the root is reached, the rule can be created by listing those conditions. The ID3 Induction tree algorithm has proven to be effective when working with large datasets that have a large number of features where it is inefficient for human experts to process. These rules are also clear and easy to understand to the average user. Induction trees also have low rates of error when classifying data with noise as long as the noise rate is not extremely high. When dealing with errors in a single attribute or multiple attributes, the tree is still able to find enough information to branch on, even if the error rate of the data are high [18]. While simple decision trees for small datasets can be created quickly by a user, large datasets with many attributes would make user creation less than ideal. Induction trees can handle large datasets with multiple attributes easily with little computational power needed to produce a simple decision tree.

To make a decision tree, the amount of information needed to classify the dataset is calculated. Then, the amount of information needed to classify the dataset after a split using each attribute is calculated. The information gain is defined as the difference between information needed to classify before the split and after the split. The attribute with highest information gain is used for the split at the root node. The process is then repeated with the remaining attributes until all are processed and the tree is grown.

C. C4.5 Decision Tree

We used C4.5 algorithm to extract rules and information from the dataset. In the preprocessing stage we converted attribute values that were continuous to discrete values. After pre-processing, data can be processed with the C4.5 algorithm using the programming language R, a statistical computing environment. Using J48, a function of the R package RWEKA created by Hornik et al., [19], C4.5 decision trees can be generated that take a formula and a dataset as input. Since the data are ready, a formula is now required. This formula tells the algorithm how the dataset attributes relate to one another. Once the data and the formula are prepared, the algorithm can start to calculate information gain. For each attribute, the information gain is calculated. Equation (1) can be used to calculate entropy.

$$entropy(D) = -\sum_{i=1}^{m} p_i \log(p_i) \qquad (1)$$

Where D is the observation vector, m is the number of classes, and p_i is the probability that D belongs to a given class. The information gain is calculated by subtracting the difference in entropy from the total amount of information contained in the data using (2).

$$Gain(A) = Info(D) - Info_A(D) \qquad (2)$$

Where A is the attribute being processed. The total amount of information can be calculated by using (3).

$$Info_A(D) = \sum_{j=1}^{v} \frac{|D_j|}{|D|} \times Info(D_j) \qquad (3)$$

Where v is the number of distinct values of attribute A, and $|D_j|/|D|$ shows the weight value of the j^{th} split of the tree. Once the information gain for each attribute is known, the attribute with the highest information gain becomes the root node in the tree and is the first split. Next, the process is repeated again for the remaining nodes and another node of the tree is created and split upon using the highest available information gain. These nodes branch out using the different conditions of the previous nodes to begin narrowing down the data with each split on information gain creating nodes that are children of their parent node. This process continues until one of a few conditions is met. If all of the records in the list at this point belong to the same class, a leaf node is created that states the class. If there is no information gain on any of the attributes or a new class is encountered for the first time, the algorithm creates a node higher up the tree to represent the expected value of the class at that point. Once all attributes have been processed, the tree is built and rules can be extracted.

Extracting rules from a full decision tree is not a simple task. Simple trees have few leaves that classify all the data. Since a large number of leaves are generated for the datasets used in this project, a selection method is taken to reduce the number of leaves to a reasonable amount. The J48 function has a default value of 25% confidence for pruning, meaning that at least 1/4th of the samples must be correctly classified for the rule to appear in the tree. The strongest rules showing the highest sample collections for each class were taken so that the rule base would be balanced for all the classes. Once the strongest rules for each class have been selected, the rule is created by listing the conditions that occur on the path from the root node to the leaf that represents the resultant class. These rules take on the format of "if *x*=*a* AND *y*=*b* then *class*=*z*" with *x* and *y* being different attributes, a and *b* being possible values for those attributes, and *z* being a possible class. Next, these rules can be used to predict the outcome of samples taken from new data that match the conditions in the rules.

D. Fuzzy Inference System

In order to evaluate the accuracy of extracted rules, a fuzzy inference system (FIS) was built using the extracted rules and the data samples were reclassified using the FIS. A FIS is a system that applies fuzzy logic to map inputs to outputs, functioning similar to an artificial neural network [20]. Fuzzy inference systems attempt to build models that can be used to predict new data. These systems allow us to model the behaviors of complex systems using rules made up of basic logic statements and then use those rules to simulate the effects on new data. In this project, the software MATLAB and the fuzzy logic toolbox is used to build a FIS.

A fuzzy inference system (FIS) essentially defines a nonlinear mapping of the input data vector into a scalar output using fuzzy rules. The mapping process involves input/output membership functions, fuzzy logic operators, fuzzy if-then rules, aggregation of output sets, and defuzzification. A FIS with multiple outputs can be considered as a collection of independent multi-input/single output systems. A general model of a fuzzy logic system (FLS) is shown in Figure 1 [21]. The FLS maps crisp inputs into crisp outputs. It can be seen from Figure 1 that the fuzzy logic system contains four components: the fuzzifier, inference engine, rule base, and defuzzifier. The rule base contains linguistic rules that are provided by experts. It is also possible to extract rules from numeric data. Once the rules have been established the FLS can be viewed as a system that maps an input vector to an output vector. The fuzzifier maps input numbers into corresponding fuzzy memberships. This is required in order to activate rules that are in terms of linguistic variables. The fuzzifier takes input values and determines the degree to which they belong to each of the fuzzy sets via membership functions. The inference engine defines mapping from input fuzzy sets into output fuzzy sets. It determines the degree to which the antecedent part is satisfied for each rule. If the antecedent part

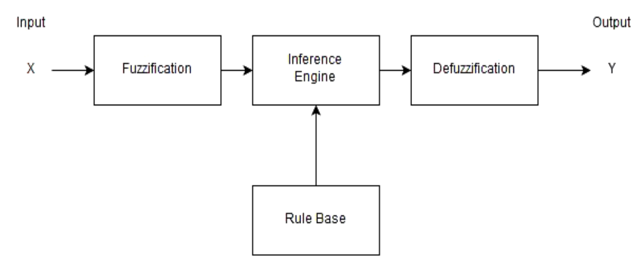

Fig. 1. Block Diagram of a fuzzy inference system (FIS)

of a given rule has more than one clause, fuzzy operators are applied to obtain one number that represents the result of the antecedent for that rule. It is possible that one or more rules may fire at the same time. Outputs of all rules are then aggregated. During aggregation fuzzy sets that represent the output of each rule are combined into a single fuzzy set. Fuzzy rules are fired in parallel, this is one of the important aspects of a FLS. In a FLS, the order in which rules are fired does not affect the output. The defuzzifier maps output fuzzy sets into a crisp number. Given a fuzzy set that encompasses a range of output values, the defuzzifier returns one number, thereby moving from a fuzzy set to a crisp number. Several methods for defuzzification are used in practice. They include: the centroid, maximum, mean of maxima, height, and modified height defuzzifier. The most popular defuzzification method is the cendroid defuzzification method. It calculates and returns the center gravity of the aggregated fuzzy set.

Fuzzy inference systems employ rules. However, unlike conventional expert systems, a fuzzy rule localizes a region of space along the function surface instead of isolating a point on the function surface. For a given input more than one rule may fire, in a FLS multiple regions are combined in the output space to produce a composite region. A general schematic of a FLS is shown in Figure 2 [17].

Creating a FIS in software consist of three primary steps: entering inputs, outputs, and rules. The inputs are the attributes of the dataset and are represented graphically in the FIS by mapping each one with a set of membership functions. For each possible value of each specific input, a membership function showing the degree of membership to a set of values is created and mapped. This fuzzification of values allows us to define how specific inputs relate to the memberships of each of the values. After each input value has been mapped, a graph similar to Figure 3 is produced. Next, the outputs are mapped in a similar fashion, only using the final possible classes for each membership function as seen in Figure 4. Lastly, the rulebase must be entered into the system. These rules are the ones obtained from the C4.5 algorithm when it was applied to the dataset. The preprocessing that was applied to the dataset earlier now proves useful when entering rules in to the FIS, where the rules must be entered using a verbose representation.

With the inputs, outputs, and rules programmed into the FIS, data can now be passed into the system to observe the -

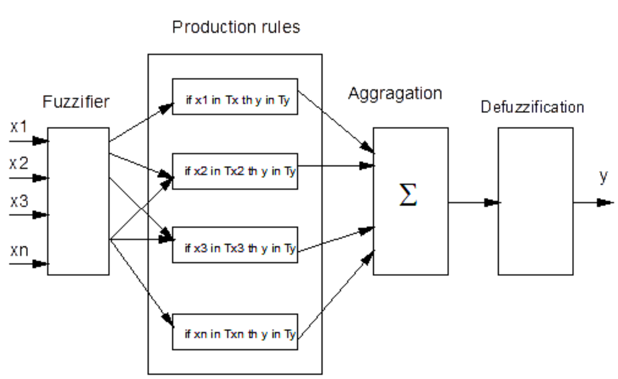

Fig. 2. Schematic diagram of a FIS

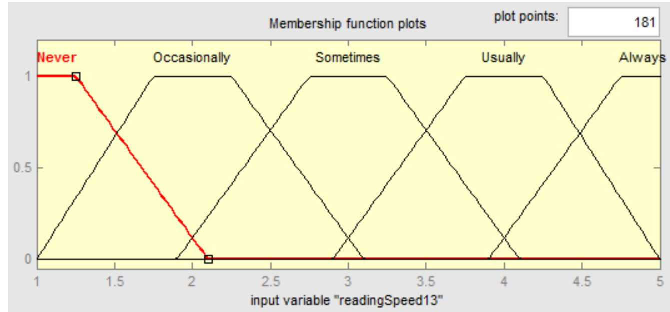

Fig. 3. Example Input Membership Functions

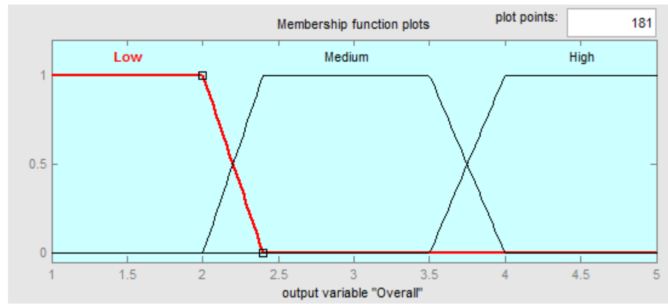

Fig. 4. Example Output Member Functions

behavior of the rules. From here, the fuzzifier component of the FIS evaluates each input into the system and finds the firing strength of each rule. The firing strength of a rule is a measure of how accurately the inputs match the conditions of the rule. Each input is matched against all rules and receives a numerical output for each rule whose conditions are all satisfied. The output of each rule is mapped to the membership functions of the output variable. This creates a shape in the membership function that shows the degree of membership as seen in Figure 5. Several rules could fire for any given input. If this happens, the output of all the rules are aggregated into one result. This aggregation combines all the shapes into a larger shape for the final result which can be seen in the bottom-right of Figure 5. To obtain a single crisp value for this range of values covered by the shape, the center of gravity is calculated. In this FIS, the centroid method was used, calculating the center of the area under the curve of the shape. Once the center of gravity of the aggregated shape is calculated, the range value at that point becomes the crisp value for the input. This crisp value is then plotted on the set of output membership functions to defuzzify it and obtain a final value which is used to determine a class for the input data. Afterwards, the next input can be processed.

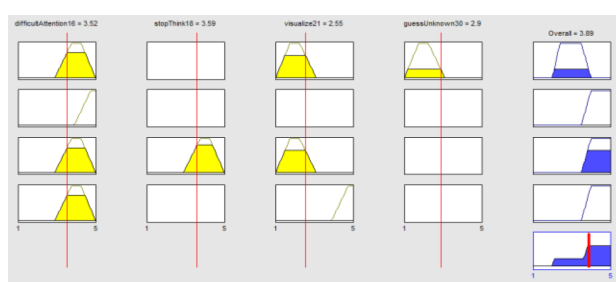

Fig. 5. Shapes from Rule Firing

III. RESULTS AND DISCUSSIONS

Once the system has been implemented, the test data can be run through the FIS to validate the data. By using the command line in MATLAB, it is possible to test each value and the system returns the resulting class. By comparing the predicted classes to the actual classes, an accuracy rating can be determined. Overall accuracy was calculated by taking the number of correct classifications divided by the total number of samples.

A. MARSI Overall Dataset

This dataset consisted of all the MARSI data, having 30 questions as attributes and 1636 records. This dataset determined an aggregated level of reading strategies for the reader by considering all reading strategies to classify them into three categories: low, medium, or high.

1. If (contentFit7 is Never) and (stopThink18 is Never) and (analyse23 is Never) then (Overall is Low)
2. If (contentFit7 is Never) and (stopThink18 is Occasionally) and (analyse23 is Never) then (Overall is Low)
3. If (contentFit7 is Occasionally) and (stopThink18 is Occasionally) and (analyse23 is Never) then (Overall is Low)
4. If (analyse23 is Occasionally) then (Overall is Medium)
5. If (Know3 is Sometimes) and (stopThink18 is Sometimes) and (analyse23 is Sometimes) then (Overall is Medium)
6. If (Know3 is Sometimes) and (analyse23 is Sometimes) then (Overall is Medium)
7. If (analyse23 is Always) then (Overall is High)
8. If (summarize6 is Usually) and (stopThink18 is Usually) and (analyse23 is Usually) then (Overall is High)
9. If (summarize6 is Always) and (analyse23 is Usually) then (Overall is High)

Fig. 6. Extracted Rules for Overall Dataset

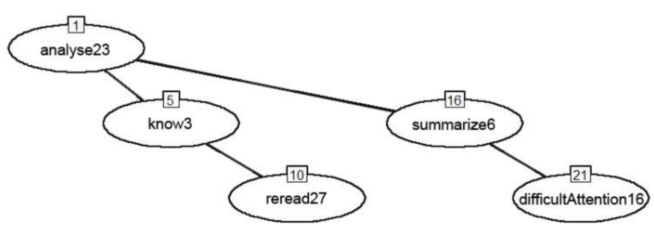

Fig. 7. A Subset of the MARSI Overall Tree

After running this dataset through the C4.5 induction tree, nine rules were selected, three from each class of high, medium, and low, that represented the strongest rules that applied to the largest sections of the data. To find the strongest rules, the rules were ranked by number of samples classified for each class, and the three highest rules that classified the most data were selected. These rules for the MARSI Overall dataset can be seen in Figure 6. These rules were derived from the tree produced from the C4.5 algorithm. The subset of the top layers of the tree is shown in Figure 7. From the tree, we can see that the attribute ‘analyse23’, corresponding to the 23rd question in the instrument, is the attribute that is the most influential on overall reading strategies. Using the C4.5 tree produced, the data can be run through the classifier again to determine accuracy. After running a confusion matrix on the MARSI overall dataset, it was found to correctly classify the data 83.33% of the time. Those rules were then taken and input into a fuzzy inference system. After processing all the data through the FIS, it was found that the FIS classified data correctly 72.55% of the time. A tool known as a confusion matrix can show induvial accuracies for each classification. The confusion matrix for the data after being run through the FIS is shown in Table 1.

TABLE I. FIS CONFUSION MATRIX FOR MARSI OVERALL DATASET

	Low	Medium	High	Row Total
Low	30	35	1	66
Medium	23	425	287	735
High	0	103	732	835
Column Total	53	563	1020	1636

B. MARSI Global Reading Strategies Dataset

The global reading strategies dataset (GLOB) is a subset of the MARSI overall dataset consisting of only thirteen of the thirty questions. After processing this dataset similarly to the first and using the same instruments to analyze the data, this dataset showed an 84.62% accuracy when using the 9 rules found to reclassify the data. After taking those rules and using them in building the GLOB FIS, classification of the data resulted in a 70.29% accuracy.

C. MARSI Problem Solving Strategies Dataset

The problem solving strategies dataset (PROB) is a subset of the MARSI overall dataset consisting of eight of the thirty questions. Applying the same process to the data showed an accuracy of 62.5% after applying the C4.5 algorithm, and an 86.76% accuracy with the PROB FIS built with the extracted rules.

D. MARSI Support Reading Strategies Dataset

The support reading strategies dataset (SUP) is a subset of the MARSI overall dataset consisting of the remaining eight questions. As with the other datasets, the MARSI SUP dataset was processed through the C4.5 induction tree to determine rules and an accuracy of 100% was observed. After taking those rules and using them to build the SUP FIS, the accuracy of the system was shown to be 68.89%.

IV. CONCLUSIONS

In this research, the C4.5 induction tree algorithm was applied to four datasets in order to obtain rules that were easily understandable and helped to show patterns in conditions that led to a classification. These rules were then tested for accuracy using a fuzzy inference system that was built for each dataset. The method was applied to the MARSI datasets – overall, global, problem-solving, and support. Rules for the systems were selected manually from a list, choosing rules that had the greatest strength. It was shown that rule generation has varying efficiency depending on the dataset used, however, the rules generated still classified the majority of the data in all datasets with the lowest accuracy being 68.89%.

Looking at the MARSI datasets, it can be seen from Table 2 that there are far more classifications of 'High' than 'Medium', and even fewer 'Low' classifications. This relationship is most likely due to the effect of the students participating in the instrument inflating their own self-assessments. It has been found that people often overstate their abilities and see themselves as above average when they actually score low in areas where they rate themselves [22]. This effect can also alter the results if the student is unskilled in the area they are evaluating themselves on. This can possibly explain how the data for the MARSI datasets are slightly skewed, having few rules generated for the 'Low' classes. Rules selected for the 'Low' classes often contained far fewer samples than the other classes, but since they had the highest sample size in their class, they were selected and used in the system. Even with the inflation of self-assessment effect providing some inaccuracy in the data, the MARSI datasets were still able to produce accurate rules, with some datasets having higher accuracy than others.

TABLE II. TOTALS FOR CLASSIFICATION AMOUNTS

		Dataset			
		Overall	GLOB	PROB	SUP
Class	Low	66	107	25	240
	Medium	735	793	317	806
	High	835	736	1294	590

Our study has shown that induction trees provide an efficient tool for extracting reliable rules from datasets such as MARSI. However, in future research, we plan to apply other methods such as neural networks, support vector machines (SVM), and K-nearest neighbor algorithm for classification and rule extraction. The usage of such methods will enable us to compare methods with respect to efficiency of rule extraction, classification accuracy, and potentially attainment of a best possible rule set. In addition, it is possible to rank attributes by their information content and use a subset of those with the highest information content to improve efficiency and possibly accuracy. The current dataset used for purposes of this study was limited to only thirty attributes and did not have demographic attributes such as age, gender, ethnicity, and student reading ability. Demographic variables such as these, and others, could have been factored into the research to show how they contribute, individually or collectively, to students' awareness and use of metacognitive strategies when reading.

REFERENCES

[1] RAND Reading Study Group, "Reading for Understanding: Toward a Research and Development Program in Reading Comprehension." Arlington, VA: RAND, 2002.

[2] S. Mitra, S. K. Pal, and P. Mitra, "Data mining in Soft Computing Framework: A Survey," IEEE Trans. Neural Networks, vol. 13, no. 1, pp. 3-14, 2002.

[3] J. Malone, K. McGarry, S. Wermter, and C. Bowerman, "Data mining using rule extraction from Kohonen self-organizing maps," Neural Computer and Applications, vol. 15, no. 1, pp. 9-17, 2005.

[4] G. Fung, S. Sandilya, and R. B. Rao, "Rule Extraction from Linear Support Vector Machines," Eleventh ACM International Conference on Knowledge Discovery in Data Mining, pp. 32-40, 2005.

[5] M. Ali, S. Qaseem, L. Rajamani, and A. Govardhan, "Extracting Useful Rules through Improved Decision Tree Induction Using Information Entropy," International ournal of Informaition Sciences and Techniques, vol. 3, no. 1, pp. 27-41, 2013.

[6] Z. Zhou, Y. Jiang, and S. Chen, "Extracting Symbolic Rules from Trained Neural Network Ensembles," AI Communications - Artificial Intelligence Advances in China, vol. 16, no. 1, pp. 3-15, 2003.

[7] J. Anderson, K. Mokhtari, and A. Kulkarni, "Assessing Metacognitive Skills Using Adaptive Neural Networks," Procedia Computer Science, pp. 294-299, 2012.

[8] T. S. Roy, N. Sirohi, and A. Patle, "Classification of Lung Image and Nodule Detection Using Fuzzy Inference System," International Conference on Computing, Communication and Automation, pp. 1204-1207, 2015.

[9] S. Sapna and A. Tamilarasi, "Fuzzy Relational Equation in Preventing Diabetic Heart Attack," International Conference on Advances in Recent Technologies in Communication and Computing, pp. 635-637, 2009.

[10] I. Mala, P. Akhtar, T. J. Ali, and S. S. Zia, "Fuzzy Rule Based Classification for Heart Dataset using Fuzzy Decision Tree Algorithm based on Fuzzy RDBMS," World Applied Sciences Journal, vol. 28, no. 9, pp. 1331-1335, 2013.

[11] S. Sajasi and A. M. E. Moghadam, "A High Quality Image Steganography Scheme Based on Fuzzy Inference System," 13th Iranian Conference on Fuzzy Systems, pp. 1-6, 2013.

[12] A. Behrouznia, M. Saveri, A. Azadeh, S. M. Asadzadeh, P. Pazhoheshfar, "An Adaptive Network Based Fuzzy Inference System-Fuzzy Data Envelopment Analysis for Gas Consumption Forecasting and Analysis: The Case of South America," International Conference on Intelligent and Advanced Systems, pp. 1-6, 2010.

[13] K. Mokhtari and C. A. Reichard, "Assessing Students' Metacognitive Awareness of Reading Strategies," Journal of Educational Psychology, vol. 94, no. 2, pp. 249-259, 2002.

[14] K. Mokhtari, and R. Sheorey, "Reading Strategies of first and second language learners: See how they read," Norwood, MA: Christopher Gordon Publishers, 2008.

[15] J. R. Quinlan, "C4.5 Programs for Machine Learning," Morgan Kaufmann, 1992.

[16] K. Jearanaitanakij, "Classifying Continuous Data Set by ID3 Algorithm", Fifth International Conference on Information, Communications, and Signal Processing, pp. 1048-1051, 2005.

[17] A. D. Kulkarni, Computer Vision and Fuzzy Neural Systems. Upper Saddle River, NJ: Prentice Hall, 2001.

[18] J. R. Quinlan, "Induction of Decision Trees," Mach. Learn., vol. 1, no. 1, pp. 81–106, Mar. 1986.

[19] K. Hornik, C. Buchta, and A. Zeileis, "Open-Source Machine Learning: R Meets Weka", Computational Statistics, vol. 24, no. 2, pp. 225-232, 2009.

[20] J-SR. Jang, "ANFIS: adaptive-network-based fuzzy inference system," IEEE Transactions on Systems, Man, and Cybernetics, vol. 23, no. 3, pp. 665-685, 1993.

[21] A. D. Kulkarni and Sara McCaslin, "Knowledge Discovery From Multispectral Satellite Images," IEEE Geoscience and Remote Sensing Letters, vol. 1, no. 4, pp. 246-250, 2004.

[22] J. Kruger and D. Dunning, "Unskilled and Unaware of It: How Difficulties in Recognizing One's Own Incompetence Lead to Inflated Self-Assessments," Journal of Personality and Social Psychology, vol. 77, no. 6, pp. 1121-1134. 1999.

Development of a Fingerprint Gender Classification Algorithm Using Fingerprint Global Features

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***Abstract*—In forensic world, the process of identifying and calculating the fingerprint features is complex and take time when it is done manually using fingerprint laboratories magnifying glass. This study is meant to enhance the forensic manual method by proposing a new algorithm for fingerprint global feature extraction for gender classification. The result shows that the new algorithm gives higher acceptable readings which is above 70% of classification rate when it is compared to the manual method. This algorithm is highly recommended in extracting a fingerprint global feature for gender classification process.**

Keywords—fingerprint; gender classification; global features; algorithm

I. Introduction

Fingerprint and other skin ridges are called dermatologlyphics. Fingerprint skin ridges have a special characteristic that can differentiate the gender of a person. The statistics of dermatologlyphics differ between gender, ethical groups, and age categories[1][2]. These categories were defined during the early investigation of fingerprint structure by looking at the intensity of ridges and ridge count [3][4][5][6][7][8].

Based on previous research [3][4][5][6][7][8], ridge density is the criteria which is most prominent to differentiate the sex of a person [9]. From these studies, we can infer that ridge density is a good feature for identifying the gender.

Many research publication works discover and appraise the weakness of gender classification accuracy problem [10], while some researcher propose of a new classification methods for gender classification problem [11][12][13] and several publications enhance the accuracy by comparing the classification rate using different classifier [3][14].

Within the last few years, researchers are still finding the best technique to estimate gender-based on fingerprint. So far, various methods have been used using fingerprint physical features like the ridge count, the ridges density and the ridges thickness. Due to the great potential of fingerprints as an efficient classification method, a researcher keeps analysing the fingerprint correlation with gender of an individual [11].

Based on the previous research in forensic area for gender classification [4][5][7][15][16][17][18][19][20][21], the process ridge count had been done manually. This process is done by calculating the ridge under a 5 mm x 5 mm square drawn on a transparent film. The ridge is also count under Fingerprint Laboratories Magnifying Glass. The process of the ridge count takes long time and a lot of energy and focus in order to avoid any error in calculation. [4][5][7][15][16][17][18][19].

Nowadays, the existence of the fingerprint gender classification method is not very good in recognizing the gender of a real person. This is due to the human errors when the process of the ridge count begins. As a feature extraction and classification part is an important step in the fingerprint gender classification process, researcher’s keeps finding the best classification method in performing the best and highly accurate method [22].

The problem always happens in gender classification because of their problem in feature extraction. The effectiveness of feature extraction depends on the quality of the images, representation of the image data, the image processing models, and the evaluation of the extracted features [22]. The calculation exactness is also depends on the quality of latent fingerprint images. If the fingerprint images are not clear and blurred, then the fingerprint images need to be recaptured and this makes the classification process longer as it is done manually. As the calculation involves human, human error factors need to be considered too before any conclusion can be derived. Image enhancement is a very important step to ensure the extraction of reliable features, especially on poor quality fingerprints [23]. The image quality of the fingerprint is important due to the fact that it is affecting the success of classification accuracy [24].

Thus, this study aims to develop a new algorithm for calculating the fingerprint global features for making the process of classifying to be easier than before.

II. Methodology

The sample of this study consists of 3000 fingerprint images which 1430 fingerprints are from male and another 1570 are from female. The fingerprint images are taken manually using the data collection form and was scanned using Fuji Xerox Docuscan C4250 with the format of Grayscale, 600dpi and JPEG.

The process of developing an algorithm begin with the calculation of the correlation of pixel value with the inch value. In order to get the value of 5 mm x 5 mm square area in pixel, some calculation needs to be proved. The process of calculation is shown below:

600 dpi =
(600 pixel)/(1 inch)≡(600 pixel)/(25.mm)≡(23.622 pixel)/(1 mm)≡(118 pixel)/5mm)

The size of pixel use in the calculation after the conversion process is 118 pixels per 5 mm. The process of developing this algorithm is involved in two phases which are Image Pre-processing and Feature Extraction. Image preprocessing focused on removing the unimportant data information of the fingerprint images. The preprocessing is implemented to get the separated of ridges and valleys image. In this study, the image is processed using normalization, binarization, complement image, and filtering image in order to get a high quality fingerprint image.

Fig. 1. Normalization

Fig. 2. Binarization

Fig. 3. Complement the image

Fig. 4. Filtering Image

For feature extraction, the calculation of Ridge Density is done by calculating the connected black and white line. The process of translating the forensic manual method to the proposed algorithm is shown in Table I.

TABLE I. COMPARISON OF FORENSIC MANUAL METHOD WITH PROPOSED METHOD

Phase	**Conventional Method**	**Proposed Method**
Image Preprocessing	1.Ten-print card containing all ten inked fingerprint impressions of an individual	1.The 10 fingerprint image has been taken manually using a data collection form and thumbprint pad. 2.The data collection document is scanned using Fuji Xerox DocuScan C4250 with the properties as below: Item Type: JPEG Image Resolution: 600dpi Dimension: 4961 x 7016 Width: 4961 pixel Height: 7016 pixel 3.From the scanned document, the process of image cropping for all ten fingerprints for each respondent is done using Matlab. 4.The image is cropped to the fixed size for all ten fingerprint of the respondent. The fixed size image is 1 inch x 1 inch. 5.Then, the image undergo a preprocessing image which is normalization, binarization, filtering, image inverting/ complement in order to get the clear ridge and valley image in order to make the calculation of the ridge easier.

Feature Extraction	1.Epidermal ridges from fingerprint samples of both men and women were counted within a 5 mm × 5 mm square drawn on transparent film. 2.The value represents the number of ridges/25 mm^2 and will be referred to as the ridge density value. 3.Fingerprints from the left hand, the square was placed to the upper right of the central core area and for the right hand, the square was placed to the upper left of the central core. The ridges are calculated on the specific square using a magnifying lens	1.In order to convert the value in inch to millimeter and find the correlation of millimeter and pixel, some calculation need to be proved. The calculation as shown below: 600dpi = (600 pixel)/(1 inch)≡ (600 pixel)/(25.4 mm)≡ (23.622 pixel)/1mm≡(118 pixel)/(5 mm) 2. The size of 5 mm after the conversion calculation is equivalent to 118 pixels. 3.Build the rectangle with the size of 118 x 118 pixels to the ulnar/ radial position and crop the specific image.  Fig. 5. Fingerprint image with the $25mm^2$ square area  Fig. 6. Fingerprint images after crop to the $25mm^2$ square size 4. Calculate the connected black and white from the image. The value of connected black and white is the number of ridge count in the image. 5. Calculate the Ridge Density using formula,

		Ridge Density = (Number of Ridge Count)/〖25mm〗^2 using formula,

III. Result and Discussion

The performance of the proposed algorithm is tested on how many readings that come out from the algorithm which can be accepted. The acceptable value is getting from the value of the ± standard deviation to the mean of each fingerprint features. The acceptable value must be in the range of the ±standard deviation with the mean of each fingerprint features.

A. Ridge Density Extract from Forensic Manual Method

Table II shows the class of mean number of ridges count and the percentages of the mean number of ridge count of male and female. The result shows that the male respondents tend to have a lower mean number of ridges density with a maximum number of 15.1-15.9 mean of ridges counts compared to female respondents with a maximum of 18.1-18.9 mean number of ridges count. In terms of percentage, 38% of the male respondents tend to have 11.1-11.9 mean number of ridges while for female respondent, the majority of the group have 15.1-15.9 mean number of ridges which accumulate 45%.

TABLE II. No. of Ridge Count Using Forensic Manual Method

		Male		Female	
Class	**Mean Number of Ridge**	**No of Participant**	**(%)**	**No of Participant**	**(%)**
A	9.1-9.9	5	4	0	0
B	10.1-10.9	35	24	0	0
C	11.1-11.9	53	38	0	0
D	12.1-12.9	33	23	0	0
E	13.1-13.9	13	9	2	1
F	14.1-14.9	2	1	12	8
G	15.1-15.9	2	1	70	45
H	16.1-16.9	0	0	35	22
I	17.1-17.9	0	0	24	15
J	18.1-18.9	0	0	14	9
Total:		143	100	157	100

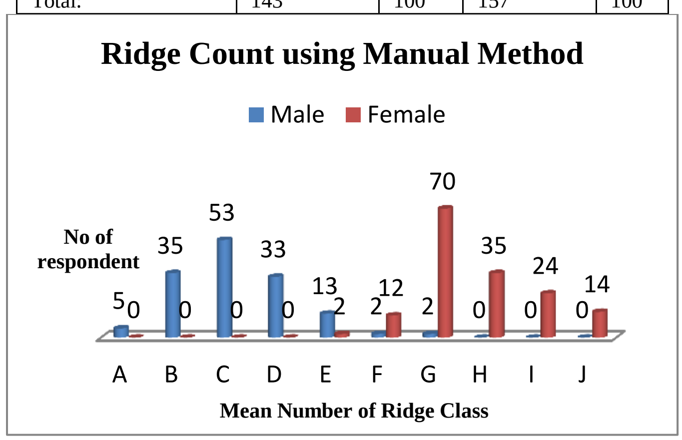

Fig. 7. Data Visualization of Ridge Count using Manual Method

Figure 7 shows the histogram the data visualization of the respondents and its ridge in both genders. It shows that the male respondents tend to have a lower number of ridges densities with maximum of it in group G compared to female respondents with maximum of it in group J. On the other hand, no female respondents were found in class A, B, C and D in which the mean number of ridge count is between 9.1 and 12.9 and no male respondents is in a class of H, I, J in which the mean number of ridges count is between of 16.1 and 18.9. From the histogram, there are an escalating number of female respondents having more ridges when the number of ridge increases from class E to class J. While for male respondents, it can be seen that the pattern is totally contrary, when the mean numbers of ridges increase after 11.1-11.9. After the calculation have been made, it is shown in Table III that mean for male and female in Malaysia is around 11.4 and 15.7 each with the standard deviation of 1.3822 and 0.9496.

TABLE III. STATISTICAL OF RIDGE DENSITY IN BOTH MALE AND FEMALE

	Male	Female
Mean	11.4	15.7
Standard Deviation	1.3822	0.9496

B. Ridge Density Extract from Proposed Method

Table IV shows the mean number of ridge count for all 10 fingerprints for each participant and percentages of mean ridges count for every class of mean. The result shows that the male respondent tends to have lower mean number of ridges with the maximum number of it in the range of group H which is 16.1-16.9 compared to female respondent with a maximum mean no of ridge in group J which is 18.1-18.9. In terms of percentage, the majority of 41% of female respondents are in group H with the range of 16.1-16.9 of a mean number of ridge while the majority of 35% of male respondent are in group C with the range of 11.1-11.9.

TABLE IV. NO OF RIDGE COUNT USING PROPOSED METHOD

		Male		Female	
Class	**Mean Number of Ridge**	**No of Participant**	**(%)**	**No of Participant**	**(%)**
A	9.1-9.9	3	2	0	0
B	10.1-10.9	37	26	0	0
C	11.1-11.9	50	35	0	0
D	12.1-12.9	31	22	0	0
E	13.1-13.9	13	9	2	1
F	14.1-14.9	2	1	12	8
G	15.1-15.9	4	3	39	25
H	16.1-16.9	3	2	65	41
I	17.1-17.9	0	0	24	15
J	18.1-18.9	0	0	15	10
Total:		143	100	157	100

Table V shows the descriptive statistical of ridge count for both male and female respondent. It shows that the mean for male and female respondent for Malaysian population is around 11.8231 and 16.3494 each with the standard deviation of 1.3793 and 1.1143. The standard error for each gender is 0.1153 for male respondent and 0.8922 for female respondent.

TABLE V. STATISTICAL OF RIDGE DENSITY IN BOTH MALE AND FEMALE

	Male	Female
Mean	11.8	16.3
Standard Deviation	1.38	1.11

From the information retrieved on the analysis shows in Table III, the results were based on 300 fingerprint images, among which 143 were males fingerprint only 111 readings from this algorithm are in the range of acceptable reading while 32 readings are out of the range. For female fingerprints, only 113 readings from 157 females fingerprint are in the acceptable range, while another 44 fingerprint reading is out of the range. This algorithm achieved 77% of the algorithm applicability for male and 72% for female. Overall acceptability of this algorithm achieved 74.5%. This result is shown in Table VI.

TABLE VI. INFORMATION RETRIEVE FROM THE ANALYSIS OF RIDGE COUNT

	Acceptable	**Not-Acceptable**	**Percentage Acceptability**
Male	111	32	77%
Female	113	44	72%

The calculation of percentage relative error using formula (1) is done in order to see the error disburse of the proposed algorithm with the manual method.

Percentage of Error =(|Actual Value- Measured Value|/ Actual Value) x 100% (1)

Male Relative Error = |11.4−11.8231|11.4 x 100% = 3.7%

Female Relative Error = |16.3494−15.7|15.7 x 100% = 4.1%

Several studies have been done by the researcher on gender classification using fingerprint, but the process of extract and calculating the fingerprint features is done manually using fingerprint laboratories magnifying glass [4][5][7][15][16][17][18][19][20][2][25][26]. Based on the previous research, the study on gender classification using fingerprint ridge density are still in trend from 2001 until 2016. The development of this algorithm will make the work easier in extracting feature and reduce the time taken in classifying gender.

From the result, it can be said that the proposed algorithm helps in extracting and calculating a fingerprint global feature which help the previous study that are done manually and the result gives a higher acceptable reading which is above 70% with the relative error is 3.7% for male and 4.1% for female. More than 2100 fingerprint images are classified as male and female. This algorithm is recommended for classifying gender using the fingerprint global feature.

IV. CONCLUSION

For conclusion, the development of this algorithm will give a benefit to the forensic area where this method is adopted from the forensic manual works in classifying gender. This algorithm achieved 74.5% of correctly classified of male and female when it is comparing with the manual method.

Our future work will be continued with the implementation of this algorithm with the data mining classifier and developing an application on gender classification using fingerprint global level features.

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REFERENCES

[1] Nigeria, Yaba Lagos. "Analysis, Design and Implementation of Human Fingerprint Patterns System "Towards Age & Gender Determination, Ridge Thickness To Valley Thickness Ratio (RTVTR) & Ridge Count On Gender Detection." *Analysis* 1, no. 2 (2012).

[2] Gnanasivam, P., and Dr S. Muttan. "Estimation of age through fingerprints using wavelet transform and singular value decomposition." *International Journal of Biometrics and Bioinformatics (IJBB)* 6, no. 2 (2012): 58-67.

[3] Ceyhan, Eyup Burak, and Seref Sagiroglu. "Gender inference within Turkish population by using only fingerprint feature vectors." In *Computational Intelligence in Biometrics and Identity Management (CIBIM), 2014 IEEE Symposium on*, pp. 146-150. IEEE, 2014.

[4] Gutiérrez-Redomero, Esperanza, Concepción Alonso, Esther Romero, and Virginia Galera. "Variability of fingerprint ridge density in a sample of Spanish Caucasians and its application to sex determination." *Forensic Science International* 180, no. 1 (2008): 17-22.

[5] Acree, Mark A. "Is there a gender difference in fingerprint ridge density?."*Forensic science international* 102, no. 1 (1999): 35-44.

[6] Nithin, M. D., B. Manjunatha, D. S. Preethi, and B. M. Balaraj. "Gender differentiation by finger ridge count among South Indian population." *Journal of forensic and legal medicine* 18, no. 2 (2011): 79-81.

[7] Nayak, Vinod C., Prateek Rastogi, Tanuj Kanchan, K. Yoganarasimha, G. Pradeep Kumar, and Ritesh G. Menezes. "Sex differences from fingerprint ridge density in Chinese and Malaysian population." *Forensic science international* 197, no. 1 (2010): 67-69.

[8] Gutiérrez-Redomero, E., M. C. Alonso, and J. E. Dipierri. "Sex differences in fingerprint ridge density in the Mataco-Mataguayo population." *HOMO-Journal of Comparative Human Biology* 62, no. 6 (2011): 487-499.

[9] Malickas, Algimantas, and Rimantas Vitkus. "Fingerprint Pre-Classification Using Ridge Density." *Informatica* 11, no. 3 (2000): 257-268.

[10] Dongre, Ganesh B., and Dr SM Jagade. "A Review and Study on Fingerprint Based Gender Classification using Classified Techniques." *International Journal of Scientific & Engineering Research* 6, no. 3 (2015): 596.

[11] Tom, Rijo Jackson, T. Arulkumaran, and M. E. Scholar. "Fingerprint based gender classification using 2d discrete wavelet transforms and principal component analysis." *International Journal of Engineering Trends and Technology* 4, no. 2 (2013): 199-203.

[12] Wadhwa, Ravi, Maninder Kaur, and Dr KVP Singh. "Age and Gender Determination from Finger Prints using RVA and dct coefficients." *IOSR Journal of Engineering (IOSRJEN)* (2013).

[13] Rajesh, D. Gnana, and M. Punithavalli. "Wavelets and Gaussian mixture model approach for gender classification using fingerprints." In *Current Trends in Engineering and Technology (ICCTET), 2014 2nd International Conference on*, pp. 522-525. IEEE, 2014.

[14] Badawi, Ahmed M., Mohamed Mahfouz, Rimon Tadross, and Richard Jantz. "Fingerprint-Based Gender Classification." In *IPCV*, pp. 41-46. 2006.

[15] Cummins, Harold, Walter J. Waits, and James T. McQuitty. "The breadths of epidermal ridges on the finger tips and palms: a study of variation."*American journal of Anatomy* 68, no. 1 (1941): 127-150.

[16] Sudesh Gungadin, M. B. B. S. "Sex determination from fingerprint ridge density." *Internet Journal of Medical Update* 2, no. 2 (2007).

[17] Kaur, Ritu, and Susmita Ghosh Mazumdar. "Fingerprint Based Gender Identification using frequency domain analysis." *International Journal of Advances in Engineering & Technology* 3, no. 1 (2012): 295-299.

[18] Kumar, Lalit, Sandeep Agarwal, Rajesh Garg, Amit Pratap, and V. K. Mishra. "Gender Determination Using Fingerprints In the Region of Uttarakhand."*Journal of Indian Academy of Forensic Medicine* 35, no. 4 (2013): 308-311.

[19] Promponmaung, P., and S. Nanakorn. "Finger ridge density of northeast Thai population." *KKU Sci J* 40 (2012): 52-58.

[20] Abdullah, S. F., A. F. N. A. Rahman, and Z. A. Abas. "CLASSIFICATION OF GENDER BY USING FINGERPRINT RIDGE DENSITY IN NORTHERN PART OF MALAYSIA." (2006).

[21] Abdullah, S. F., A. F. N. A. Rahman, Z. A. Abas, and W. H. M. Saad. "Multilayer Perceptron Neural Network in Classifying Gender using Fingerprint Global Level Features." *Indian Journal of Science and Technology* 9, no. 9 (2016).

[22] Bhuyan, Monowar H., and D. K. Bhattacharyya. "An Effective Fingerprint Classification and Search Method." *arXiv preprint arXiv:1211.4503* (2012).

[23] Khan, Asif Iqbal, and M. Arif Wani. "Strategy to extract reliable minutia points for fingerprint recognition." In *Advance Computing Conference (IACC), 2014 IEEE International*, pp. 1071-1075. IEEE, 2014.

[24] Dolezel, Michal, Eva Brezinova, Jaroslav Urbanek, Martin Drahansky, and Tai-hoon Kim. *Influence of Skin Diseases on Fingerprint Quality and Recognition*. INTECH Open Access Publisher, 2012.

[25] Soanboon, Pattanawit, Somsong Nanakorn, and Wibhu Kutanan. "Determination of sex difference from fingerprint ridge density in northeastern Thai teenagers." *Egyptian Journal of Forensic Sciences* (2015).

[26] Taduran, Richard Jonathan O., Anna Katrina V. Tadeo, Nadine Anne C. Escalona, and Grant C. Townsend. "Sex determination from fingerprint ridge density and white line counts in Filipinos." *HOMO-Journal of Comparative Human Biology* (2015).

Towards Improving the Quality of Present MAC Protocols for LECIM Systems

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***Abstract*—Wireless networking system is quickly growing in the field of communication technology due to its usefulness and huge applications. To make the system more effective to the users its lower energy consumption, security, reliability and lower cost issues must be considered under any circumstances. Low energy wireless is exceedingly required because the sensors are frequently located where mains power and network infrastructure are not reliably available. The recent development of Low Energy Critical Infrastructure Monitoring (LECIM) has vast applications including: Water leak detection, Bridge/structural integrity monitoring, Oil & gas pipeline monitoring, electric plant monitoring, public transport tracking, Cargo container monitoring, Railroad condition monitoring, Traffic congestion monitoring, Border surveillance, Medical alert for at-risk populations and many more. This proposal Low Energy Critical Infrastructure Monitoring (LECIM) is proposed by the Task Group 4k under IEEE P802.15 WPAN. Although many issues related to its quality are involved, but several Media Access Control (MAC) protocols with different objectives were proposed for LECIM. In this research paper, issues related to energy consumption and wastage in LECIM system, energy savings mechanism, relevant energy conscious MAC protocols have been briefly studied and analyzed. Science Direct, Elsevier, Springer, IEEE Explore, Google Scholar and Wiley digital Library databases were used to search for articles related to the existing MAC protocols well suited for LECIM system. Finally, some ideas have been proposed towards developing energy efficient MAC protocol for LECIM applications in order to fulfill and satisfy the major issues of LECIM quality.**

Keywords—wireless networking; LECIM; IEEE P802.15; WPAN; MAC

I. Introduction

In the practical point of view the usefulness of wireless sensor networking (WSN) system requiring certain criteria including lower energy consumption, security, reliability and lower cost. Low energy wireless is particularly required because the sensors are commonly located where mains power and network infrastructure are not reliably available. The recent development of Low Energy Critical Infrastructure Monitoring (LECIM) has vast applications including: Water leak detection, Bridge/structural integrity monitoring, Oil & gas pipeline monitoring, electric plant monitoring, public transport tracking, Cargo container monitoring, Railroad condition monitoring, Traffic congestion monitoring, Border surveillance, Medical alert for at-risk populations and many more. Low Energy Critical Infrastructure Monitoring (LECIM) is proposed by the Task Group 4k under IEEE P802.15 WPAN.

Although many issues related to developing efficient LECIM applications can be summarized like, protection of the sensed data, accessing the shared medium in LECIM network; endpoints sleep time; proper coordination between coordinator and endpoints basically the way of knowing how the endpoints will know that the coordinator wants to send them the data is a challenging job where battery power must work for several years; lack of energy conservation mechanism related to its quality are involved, where most of the existing MAC protocols that support wireless sensor networks can't support these issues properly; formative the status of the channel, in LECIM this is very important because most of the nodes in LECIM system are situated in long distance and the distance among the nodes are also long, the large number of endpoints are also a significant factor. In order to solve this problem the existing contention-based and scheduled-based MAC protocols are not the appropriate solution, it needs to give more attention to solve the above mentioned problems. In this paper, we are expecting to analysis and propose some new ideas for improving MAC protocol for LECIM system, which could fulfill and satisfy the major issues of LECIM quality.

The rest of the paper is structured as follows. In Section II, major challenges, constraints and characteristics of low energy critical infrastructure monitoring; in Section III, sources of energy wastage in LECIM system are studied; in Section IV, we discussed communication patterns and energy consumption measuring system; in Section V, we discussed some mechanisms to reducing energy wastage in LECIM; in Section VI, major MAC requirements for LECIM system are defined, in Section VII, MAC protocol types in applications of LECIM system are briefly discussed; in Section VIII, we proposed some ideas for improving better performance and energy efficiency in MAC for LECIM system. Finally, we concluded and discussed future work in Section IX.

II. Major Challenges, Constraints and Characteristics of Low Energy Critical Infrastructure Monitoring

Efficient LECIM network including its infrastructure and applications is the important issue for LECIM system. The IEEE TG4K group facilitates single point to several thousands of point's communication for critical infrastructure monitoring containing one coordinator and multiple end points. In this process, coordinator is mains powered and end points are battery powered [1] [2]. The main characteristics and challenges for LECIM system is illustrated in the following Table I [3] [4] [5].

TABLE I. CHARACTERISTICS AND CHALLENGES FOR LECIM SYSTEM

LECIM Requirements Types	Major Characteristics and Challenges
Requirements based characteristics: Low energy, long lifetime, scalability, reliability, availability, robustness, maintainability, and security are network based requirements, where large path loss, minimal infrastructure requirements, and multi-year battery life are applications based requirements.	Simultaneous operation for at least 8 co-located orthogonal networks
	Application data rate vary from 1 to 40 kbps
	Propagation path loss of at least 120 dB
	Communication between main-powered coordinator and large number of endpoints, >1000 endpoints per mains powered infrastructure
	Asymmetric application data flow. Data flowing from all or a group of sensors to the central unit and vice versa.
	Ultra-low maintenance traffic
	Low power consumption, end point need to periodically go to sleep to conserve energy
	High channel access efficiency is required
	Primarily outdoor environment with minimal network infrastructure
	Long deployment life with/ without human contact (long lived infra more than 10 years life like network carrier's infra, ease maintained monitoring network, high degree of freedom to start the monitoring/maintenance business)
	Need low energy operation necessary for multi-year battery life (>20 year)
	Tolerant to data latency
	Small, infrequent messages
	Network devices: Coordinator (Collector) typically mains powered (rarely available). End point devices are typically battery powered (Battery operation (up to 20 years), low energy consumption, Low duty cycle). No mobility of end devices but portability for coordinator. High network dynamics.
	Low node density(long range)
	Mobility (Asset tracking, Dynamic fail-over)
	Worldwide use(Operates in all regulatory domains, Low transmit power compliant with international regulations)
	Low cost(Low operational cost: unlicensed, lightly licensed spectrum, Low infrastructure, maintenance , and system cost, Ease of deployment)
	Small device with high applications dependence, with limited memory, computing, transmitting and limited energy resources.
	Must be compatible with existing MAC
	PHY packet size for LECIM: Typical packet duration "real world" ranges from < 1ms to ~16ms
	Aim to collect the scheduled and event data
	Aim to minimize the network maintenance traffic and endpoint active durations
	Aim to collect real time and non-real time data
	Communication patterns: Periodic, event-based and query-based

III. STUDY AND ANALYSIS OF SOURCES OF ENERGY WASTAGE IN LECIM SYSTEM

Major sources of energy waste of low energy critical infrastructure monitoring (LECIM) based on wireless sensor network (WSN) at medium access communication are depicted in the following Table II.

Sensor node in WSN, the main sources of energy consumption, is divided into three activities including (a) sensing, (b) computation (data processing), and (c) radio operations or communication. Out of those three sources, energy loss due to radio operation or communication for data transmission is the maximum one where energy consumed for radio transmission is directly proportional to distance [6] [7] [8].

Energy waste through communication depends on sensor nodes include theses technological and physical characteristics such as collision, overhearing, control packet overhead, over emitting, idle listening, traffic fluctuation, packet forwarding, excessive state changes of the radio circuit, increased latency [9]-[13]. It's notable that, idle listening is a major cause of energy waste [14].

TABLE II. STUDY AND ANALYSIS OF SOURCES OF ENERGY WASTAGE IN LECIM SYSTEM

Source of Energy Wastage	How Energy Is Wasted?
Collision	In any event where multiple frames are received at the same time, it may damage the resulting signal and may also cause to loss all information, which requires re-transmission of collided packets. Collision results in wasted energy.
Overhearing	Message or packets are transmitted to wrong destination/nodes where its original destination is other nodes. Overhearing results in wasted energy.
Idle Listening	Occurs when the radio of the node is always on and listening to idle channel or medium even while there is no transmission. This is another source of wasting energy.
Over emitting	Messages or packets are continuing to transmit even when the destinations are not ready for receiving them; as a result, energy for sending the message is wasted.
Control Frames Overhead	Control data or frames or packets containing protocol information which are transmitting or exchanging instead of application data. Energy is consumed for transmitting and receiving these frames within medium or channels. This results in wasted energy.

IV. STUDY AND ANALYSIS OF SOURCES OF ENERGY WASTAGE IN LECIM SYSTEM

Several communication models namely broadcast, converge-cast and local gossip in WSN has been used for short and long distance based applications [15]. Transmitting necessary information to all the sensor nodes of the network a broadcast pattern is used by a sink node; in converge-cast pattern a group of sensors communicate to a specific sensor; and the sensors that detect an event communicate with each other locally is defined by local gossip pattern. Energy consumption in communication pattern depends upon its operating states which are divided into four sub-states namely transmit state, receive state, idle state, and sleep state. Transmit and receive states are used for sending and receiving data; the default state of WSN is idle state, and sleep state consumes very less energy than any other above mentioned states [16] [17]. Average power consumption of different sub-states in operating state is defined by the following ratio [18]: Transmit: receive: idle: sleep= 40.25%: 29.1%: 25.3%:5.4%

Total energy consumption 'E' in operating state to transmit 'k' bit is illustrated by the following equation [19]:

$$E = Pactive \times Tactive + Psleep \times Tsleep + Ptransient \times Ttransient + Pidle \times Tidle \quad (1)$$

Where Pactive , Psleep , Ptransient , Pidle are the power consumption and Tactive , Tsleep , Ttransient , Tidle are the interval or duration of time that a transceiver waits or stays at its active, sleep, transient and idle mode respectively.

V. Mechanism to Reduce Energy Wastage in LECIM

In order to increase network's life time and maximizing node in LECIM it's very important to reduce energy waste throughout the system and to enhance the performance of medium access control (MAC) protocol. Different wake up mechanisms could be used to enhance the performance of MAC protocol. Due to the unlimited power consumption of nodes in LECIM and long duration of operation energy efficiency is an important issue. It is generally not possible and practical to recharge or replace the exhausted batteries for sensor nodes in the network. So enhancing the lifetime of network as well as the sensor nodes means enhancing batteries life time.

As discussed earlier the energy consumption in sleep state is lower than idle listening state, so another good mechanism would be to maximize sleep period of the node in MAC layer, while conserving the highest throughput, the lowest latency, and the utmost energy conserving in a WSN [6]. In order to save the transmission energy, several techniques are being used including, energy-aware routing pursuing multi-hop paths, providing time-based medium access control (MAC) by limiting the potential for collisions and minimize the energy consumed in the receiver by turning the radio off when it is idle [20]. Power savings mechanism in MAC layer is classified into three basic classes and they are: effective use of the PHY layer services, optimized media access protocol structure, and useful system design [21].

The power or energy saving mechanisms [22] [23] is illustrated in Table III. Idle listening is the major cause of energy waste, so it is important to introduce suitable MAC protocol which can reduce or prevent energy wastes due to idle listening. Four techniques are being used to avoid idle listening including static sleep scheduling, dynamic sleep scheduling, preamble sampling, and off-line scheduling. Several MAC protocols are already been introduces based on these techniques which are broadly classified into: CSMA, TDMA, hybrid and cross-layer optimization [14]. Using the mechanism mentioned in the following Table IV we can easily measure the performance of energy conscious MAC protocol [24]. In LECIM system the main goal of MAC protocol is to minimize the energy waste due to idle listening, overhearing and collision.

TABLE III. Classification of Energy Savings Mechanisms

Energy saving mechanisms	**Activity**
Adaptive duty cycling protocols	Reduction energy communication waste. Reducing idle listening through Duty cycling.
Wakeup on-demand protocols	Reduction energy communication waste. Reducing idle listening.

TABLE IV. Mechanism to Measure the Performance of Energy Conscious Mac Protocol

Matrices	**Explanation**
Energy consumption per bit	$\frac{\text{The total energy consumed}}{\text{total bits transmitted}}$, this is the proper way to define energy efficiency of the sensor nodes. The unit of energy efficiency is joules/bit. The lesser the result of ration, the better is the efficiency of a protocol in transmitting the information in WSN by satisfying all the major sources of energy waste in WSN including sleep and idle listening, collisions, overhearing, control packet overhead, message passing, etc.
Average Delivery Ratio	The average packet delivery (ratio) is $\frac{\text{the number of packets received over all the nodes}}{\text{the number of packets sent over all the nodes.}}$
Average Packet Latency	The average time requires by the packets to reach to the sink node.
Network Throughput	The total number of packets delivered at the sink node per time unit is defined by network throughput.

There are many reasons behind energy consumption in LECIM in WSN as explained earlier. Based on these reasons as mentioned in Table I some approaches are also proposed which are illustrated in Table V below. Approaches those have been proposed in many research papers for wireless systems in general can easily be added to a large variety of WSN MAC protocols.

TABLE V. APPROACHES TO REDUCE ENERGY CONSUMPTION

Approaches	Description
Reducing Collisions	CSMA/CA (CSMA/Collisions Avoidance) [25]: to avoid the collision prior to data transmission CSMA/CA exchanges RTS (Request To Send) and CTS (Clear To Send) packets. Due to the small size of RTS packets, the probability of them colliding is low. The improve version of CSMA/CA is MACA (Multiple Access Collision Avoidance) which adds a random back-off time before the transmission of RTS packet to avoid collisions. [26]. Both the above mentioned techniques aim at reducing collisions by equally trying to protect all transmitted packets.
Reducing Overhead	CSMA/ARC (Adaptive Rate Control) [26]: it omits the RTS/CTS exchange technique or avoids using RTS/CTS altogether for reducing the overhead and applies a back-off that is shifted according to the application periodicity while ensuring fairness between the forwarded traffic and the generated traffic.
Reducing Overhearing	PAMAS (Power-Aware Multi-Access with Signaling) [28] is based on MACA. PAMAS uses separate channel for RTS/CTS exchange where during transmission an unused node may switch off its radio to avoid overhearing.
Reducing Idle Listening	The IEEE 802.11 PSM (Power Save Mode) [29] for BSS (Basic Service Set) is a good approach for reducing idle listening which ultimately saves unnecessary energy waste in wireless networks. It places nodes to sleep as much time as possible for avoiding and reducing overhearing and overhead.

VI. MAJOR MAC REQUIREMENTS FOR LECIM SYSTEM

A different computation and communication infrastructure is provided by WSN which is based on both physical characteristics including the large scale of deployment, inadequate computing capability, and limitations on power consumption; and typical applications including tracking objects or detecting events. As a result, the requirements for the MAC layer of a LECIM system in WSN are clearly different from those for traditional networks [30]. The major requirements for the MAC layer in a LECIM system [31] should be as follows as depicted in Table VI.

TABLE VI. MAC REQUIREMENTS FOR LECIM SYSTEMS

Objective	MAC Requirements
An efficient MAC protocol for LECIM in WSN should contain these attributes	Assured and secured link access on low duty cycle with low energy.
	Maintain and support to fair access between nodes.
	Avoiding contention-based protocols (control packets overhead and active sensing of the medium are performed by these protocols) to minimize contention on a link (distribute access loads on slotted link) which is inefficient in terms of energy consumption.
	Time-stamping (global time synchronization, adjust clock drift with light overhead)
	Support to ease installation and maintenance.
	Support to make network structure simple
	Optimized to network configuration
	Real-time or Quality-of-Service (QoS) requirements: due to the importance of data availability and transmission requirements including timely detection, processing, and delivery of data in wireless applications the MAC layer should support real-time guarantees or QoS features in WSNs.
	Scalable and decentralized protocol: due to the large scale of sensor network and a large set of sensor nodes in the networks the most algorithms running in WSNs need to be decentralized.
	Power aware: due to the idle mode of operation and transmission overhearing among sensors there is a possibility of power consumption in WSNs and it needs to deploy MAC protocol to save power consumption by putting the node to sleep to save power.
	Collisions should be avoided because it causes energy wastage due to packet drop (thus reduce throughput).
	Packet drop should be prevented.
	Flexibility: MAC layer of WSNs should adopt a variety of network traffic patterns including rate-based or burst; reliable or best effort, etc these networks are often application specific.

VII. MAC PROTOCOL TYPES IN APPLICATIONS OF LECIM SYSTEM

Low energy consumption is the major issue in any wireless application including LECIM. Therefore designing, implementation and performance of energy efficient MAC protocol is a vital issue. Contention-based MAC protocols don't allow communication traffic (flow according to a preset schedule) that's why it's a major concern of large energy consumption, but a time division multiple access (TDMA) based MAC allows communication traffic which reduces energy consumption and extends the life of WSNs. In these time-based MAC enabled WSNs, the nodes can turn off their transmitters or receivers whenever it requires and collision among nodes can also be avoided because each of the nodes has its own time slots which reduce wastage of energy in communication. [32] [33]. The way of prolonging the network/node lifetime in LECIM depends on energy efficient MAC protocols including synchronous MAC protocols and asynchronous MAC protocols. Energy waste is reduced in synchronization because in this mode nodes keep awake only at a specified time and also synchronous protocols maintain a schedule, where, sensor nodes independently schedule their awake period in asynchronous MAC protocols to periodically check the channel while avoiding the synchronization overhead and introducing long latency and excess energy consumption [34]-[36].

There are five categories of MAC protocols specifically designed for WSNs as mentioned below: 1) Scheduling based or contention free or reservation based or cluster based MAC or channel partitioning MAC or controlled access protocol; 2) Collision free MAC protocols; 3) Contention based or channels polling or low power listening or cycled receiver or random access MAC or preamble sampling; 4) Scheduled-contention based MAC protocols or common active period protocol; and 5) Hybrid schemes or protocols.

The three most suitable MAC approaches to designing an energy efficient MAC protocols are Channel Polling (Low power listening-LPL), Scheduled contention, TDMA – contention free /cluster-based MAC protocols [37-38].

In the upper portion of both tables, Table VII, Table VIII and Table IX as mentioned bellow present the characteristics of the LPL, schedule-contention, and TDMA mechanisms for wireless sensor network based applications [37-47].

As mentioned, most of the existing MAC protocols are designed for a single channel only, they do not operate on Multi-PHYs simultaneously. Since different bands have different characteristics in terms of data rate, number of sub-channels in a particular frequency band/channel, and data prioritization where a good MAC protocol for LECIM should enable reliable operation on MICS, ISM, and UWB etc bands simultaneously, hence MAC transparency has been a hot topic for the MAC designers [48]. Energy saving or energy consumption issue in LECIM MAC is related to synchronous or asynchronous, beacon or preamble, and different periods of wake up and sleep modes. Idle listening dominates the total energy consumption in conventional power management schemes which is based on either periodic wake-up or sleep schedules. Sleep mode power consumption is much less than idle power consumption, which is near to 0.003 mW [49].

The MAC protocols discussed in Tables (VII-IX) in most of the cases cannot satisfy all the requirements of LECIM. Most of the traditional MAC protocols don't focus on energy conservation a mechanism which is one of the most important requirements of LECIM; they mainly focused on bandwidth utilization and throughput. On other hand contention-based protocols are used to determine the status of the channel supported by, however, this is not always guaranteed in LECIM due to the long distance among the nodes. However scheduled-based protocols provide good solutions for clear channel assessment problems, but due to large number of endpoints and event based traffic these are also not suitable for LECIM. MAC using wakeup radio is also proposed for better communication in LECIM networks.

Large network size, scalability, energy consumption issue including idle listening and delay, long battery lifetime, and security must be the major design issue for constructing any MAC protocol for LECIM.

VIII. Proposed Ideas to Ensure Better Performance and Energy Efficiency in MAC for LECIM

a) MAC Protocol with adjustable sensor Sleep Mode.

b) Reduced idle listening based medium access control (MAC) protocol: idle mode of operation should be minimized.

c) Periodic wake-up and listen technique for sensor network.

d) Collision and overhearing avoidance: Interfering nodes go to sleep after they hear an RTS or CTS packet. Collision leads to packet drop, thus reduce throughput and cause energy wastage.

e) Communication and transmission overhearing among sensors must be minimized.

f) Maintaining synchronization: synchronization required for the listen and sleep schemes among neighboring nodes.

g) Proper radio network architecture (diversity) for improving communication reliability in application in wireless sensor network based on heterogeneous and time-varying environmental conditions.

h) Introducing newly evolved communication pattern e.g. communication pattern multicast, in this pattern a sensor sends a message to a specific division or subset of sensors.

i) Introducing energy efficient buffer size of sensors. Packet drop should be prevented due to inadequate or limited buffer capacity causes high energy consumption.

j) Protocol should adapt to changes in network topology.

k) Ensuring reliable transmission with better maintenance of latency.

TABLE VII. THE MAJOR CHARACTERISTICS OF LOW POWER LISTENING-LPL MAC PROTOCOL, AND A WIDESPREAD STUDY OF THE EXISTING PROTOCOLS IN THE PERSPECTIVE OF ENERGY EFFICIENCY FOR LECIM

<table>
<tr><td colspan="6">Channel polling or Low Power Listening-LPL
LPL is unable to contain or accommodate a periodic traffic and low duty cycle nodes in wireless sensor network based applications.</td></tr>
<tr><td colspan="4">Channel polling or Low power listening (contention based LPL)</td><td colspan="2">Scheduled listening and LPL</td></tr>
<tr><td colspan="4">Major reasons of energy wastage in contusion based LPL including: a. node periodically wakes up, b. turns radio on and c. checks channel.
Result: low energy wasted on idle listening, and high energy wasted on transmissions (long preambles).
Limitation: Overhearing-non-targeted receivers who sample the channel during preamble transmission have to wait until the end of the preamble to go back to sleep. Energy expenditure is a function of density as well as traffic load, where entire preamble needs to be sent before data transmission.</td><td colspan="2">In terms of throughput and delay it provides a good transaction between energy consumption, complexity and performance. It attains the benefits of scheduled MAC protocols because of its simple operation of unscheduled MAC protocols, as well as the low consumption and cost-free maintaining and sharing the schedule.</td></tr>
<tr><td colspan="6">Channel polling or low power listening-LPL (contention based) MAC protocols: Adaptability to LECIM</td></tr>
<tr><td>WiseMAC</td><td>B_MAC</td><td>TICER/ RICER</td><td>STEM</td><td>X-MAC</td><td>A MAC Protocol using a Wakeup Radio: M.J. Miller, others</td></tr>
<tr><td>1. Organized randomly,
2. well for high traffic applications
3. it supports mobility,
4. Min/ low and max/ high power consumption in low and high traffic conditions,
5. Finally, low delay.</td><td>1. Low power Consumption on MAC Protocol.
2. Nodes wake up and perform channel sensing periodically
3. Good for high traffic application
4. Energy wasted due to idle listening and transmissions (on link preamble)</td><td>1. Significant decrease/ reduction of power consumption if wake up period is optimal.
2. Permit efficiently trade-off between energy and latency</td><td>1. Good for periodic traffic especially for low traffic applications.
2. Appropriate to handle irregular sporadic events due to a divide or separate control sub-channel.
3. Difficult to handle irregular events when the transfer or traffic loads are high.</td><td>1. Evade overhearing problem.
2. It saves energy at both the transmitter and receiver because of its strobe preamble approach
3. It allows for lower latency</td><td>1. It reduces energy consumption.
2. Outperforms STEM in energy efficiency and latency.</td></tr>
<tr><td colspan="6">Proposed protocols for scheduled listening and LPL</td></tr>
<tr><td colspan="3">Scheduled Channel Polling MAC (SCP-MAC): Hybrid approach</td><td colspan="3">Receiver Initiated MAC: RI-MAC</td></tr>
<tr><td colspan="3">1. It coordinates and synchronizes neighbor’s channel polling time.
2. Reason of energy saving: a short wake up tone wakes up receiver.
3. Advantage: it is efficient for both unicast and broadcast packets.</td><td colspan="3">1. It minimizes idle overhearing in dense networks.
2. Advantages: Sender does the idle listening, and receiver transmits beacons.</td></tr>
</table>

TABLE VIII. THE MAJOR CHARACTERISTICS OF CONTENTION-BASED MAC PROTOCOL AND A COMPREHENSIVE STUDY OF THE EXISTING PROTOCOLS IN THE CONTEXT OF ENERGY EFFICIENCY IN LECIM

<table>
<tr><td colspan="5">Scheduled-contention/ contention based MAC Protocol/ Random access MAC</td></tr>
<tr><td colspan="5">Basic characteristics including:
1. Contention-based MAC such as Carrier Sense Multiple Access/ Collision Avoidance (CSMA/CA) protocols nodes competes for the channel to transmit data.
2. In this scheduled-contention method, nodes must perform clear channel assessment (CCA) before transmission of data.
3. In this mode, if the channel is busy, the node defers its transmission till it becomes idle.
Main reasons of energy (extra) consumption:
1. In a scheduled-contention mechanism, both schemes are combined to gain scalability and to avoid collision during transmission
2. In this mechanism, the nodes become accustomed a common schedule for data communication.
3. During a synchronization period of this mode schedules are exchanged periodically.
4. If two neighboring nodes reside in two different clusters, they keep the schedules of both clusters resulting in extra energy consumption.
5. Listening for full contention period, even listening before transmitting.
6. Although the mechanism is synchronous, but low duty cycle nodes don’t need frequent synchronization/exchange of schedules in wireless sensor network based applications.</td></tr>
<tr><td colspan="5">Existing contention-based MAC protocols: Adaptability to LECIM</td></tr>
<tr><td>Sensor-MAC (S-MAC)</td><td>Pattern-MAC (PMAC)</td><td>Timeout MAC(T-MAC)</td><td>Dynamic Sensor-MAC (DSMAC)</td><td>Sleep Scheduled Delay Efficient (DESS)</td></tr>
<tr><td>Major issues including:
1. Low throughput, overhearing and collision may cause if the packet is not intended to listening node.
2. Good for high traffic</td><td>1. Adjustment and adaptation to changes and modification might be slow
2. Loosely synchronized
3. High throughput under</td><td>1. Improved version of SMAC.
2. It does not use fixed active period. But it has the capability to abridge or shorten the active period if the channel</td><td>1. Better delay
2. Using dynamic sleep scheme to save energy.</td><td>1. Enhanced or improved delay for the topology like: grid and tree
2. Random or arbitrary topology is not guaranteed even by better delay.</td></tr>
</table>

applications. 3. Appropriate for applications where throughput is not a principal concern e.g. in-body medical applications.	heavy traffic. 4. Good for delay-sensitive applications.	is idle for a short time. 3. In this mode, in the case of data, the node remains active till data reception or until the active period ends. 4. In this mode better delay, and gives better result under variable load, because packets are sent in burst, 4. Excellent for high traffic applications. 5. The nodes may lose synchronization due to its early sleep problems.		3. This mode is loosely and insecurely synchronized.

TABLE IX. THE MAJOR CHARACTERISTICS OF SCHEDULED-BASED MAC PROTOCOL AND A COMPREHENSIVE AND WIDESPREAD STUDY OF THE EXISTING PROTOCOLS IN THE CONTEXT OF ENERGY EFFICIENCY FOR LECIM

Scheduled-based/ contention-free/ cluster-based MAC Protocol

Basic characteristics including:

1. Time Division Multiple Access (TDMA) is a schedule-based or contention-free of cluster-based multiple access technique
2. In this technique transmission of packets are administered in the form of time frames and time slot.
3. In this mode, a time slot can be seen as a devoted transmission resource. It's used to carry data with minimum or no overhead.
4. In this technique, the channels are particularly divided into fixed or variable time slots which are assigned to a particular sensor node to transmit during its slot period.
5. In this protocol, nodes are collision-free because slots are pre-defined and allocated to individual nodes at the beginning,
6. It requires a good synchronization scheme.
7. There are no idle listening and overhearing issues are visible in this protocol due to its reduced duty cycle mechanism.
8. It is found that Scheduled-based/ contention-free/ cluster-based MAC Protocol is more appropriate for non-dynamic type of networks (with a limited number of sensors generating data at a fixed rate).

Reasons behind energy efficiency:

1. Time division multiple access (TDMA) or schedule-based protocol can easily support low duty cycles, which is one of the important reasons of energy efficiency.
2. It can easily avoid usage of extra energy that leads reducing energy waste from all major sources [collision, idle listening etc.].
3. Having low duty cycle nodes it doesn't require frequent or regular synchronization at the beginning of each super-frame.

Existing scheduled-based MAC protocols: Adaptability to LECIM

Flow-Aware Medium Access (FLAMA)	**LEACH**	**PACT**	**Ultra low power MAC or BSN MAC**
Main characteristics including: 1. Low delay 2. Superior end-to-end reliability 3. Remarkable energy savings. 4. It requires more support for multiple channels 5. Requires time synchronization 6. Good for low-power applications 7. Adaptable to high traffic applications.	1. It is distributed, 2. It doesn't require any global knowledge 3. Extra overhead for dynamic clustering. 4. Network's coordinator can perform/ act as a cluster-head (depending on minimum communication energy).	1. Major characteristics including, high traffic overhead 2. Idle listening 3. Requires (lacks) support for dynamic network 4. Low overhead 5. Expanded/ prolonged network lifetime 6. Good for low delay applications	1. It is an adaptive, feedback-based MAC protocol. 2. It is an IEEE 802.15.4-compatible MAC protocol. 3. Better performance in energy efficiency and latency. 4. Better in energy critical nodes. 5. MSN-MAC can improve the energy efficiency and prolong sensors' life time.

IX. CONCLUSION

In this paper, the researchers have presented issues related to energy consumption and wastage in LECIM system, energy savings mechanism. We have also studied and analyzed LECIM relevant energy conscious MAC protocols. Finally, some recommendations have been proposed for developing energy efficient MAC protocol to satisfy the major issues of LECIM quality.

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REFERENCES

[1] Seong-Soon Joo, Jong-Arm Jun, Cheol-Sig Pyo, MAC Proposal for Low-Energy Wide Area Monitoring, 15-11-0597-00-004k-lecim-mac-proposal-for-tg4k.ppt

[2] P. Kinney, "LECIM Call for Proposals, IEEE P802.15-11-0147-02-004k, 2011, https://mentor.ieee.org/802.15/documents

[3] David Howard, SG Low Energy, Critical Infrastructure Monitoring (LECIM) Project Draft PAR, 15-10-0756-09-leci-sglecim-par-draft.docx

[4] Yang Yang, Xiang Wang, Heqing Huang, Jie Shen, Tao Xing, Haitao Liu, Betty Zhao, 'Low Energy MAC Proposal for TG4k_WSNIRI', 15-11-0596-00-004k-wsniri-low-energy-mac-proposal-for-tg4k.ppt

[5] Kyungsup Kwak, Jaedoo Huh, Hyung Soo Lee, M. Al Ameen, Niamat Ullah, M.S. Chowdhury, 'A Dynamic Framed Slotted ALOHA protocol for LECIM Networks', 15-11-0486-03-004k-inha-etri-tg4k-proposal.pptx

[6] I. Demirkol, C. Ersoy, and F. Alagoz, MAC Protocols for Wireless Sensor Networks: A Survey, IEEE Communication Magazine, Vol. 44, Issue 4, pp.115-121, April 2006.

[7] S. Singh and C.S. Raghavendra, "PAMAS: Power Aware Multi-Access protocol with Signaling for Ad Hoc Networks", *ACM Computer Communications Review*, July1998.

[8] P. Havinga, G. Smit, "Energy-efficient TDMA medium access control protocol scheduling," in the *Proceedings of the Asian International Mobile Computing Conference (AMOC 2000)*, November 2000.

[9] Sai Anand Gopalan, Jong-Tae Park, Energy-Efficient MAC Protocols for Wireless Body Area Networks: A Survey, School of Electronics Engineering, Kyungpook National University Daegu, South Korea

[10] W. Ye, J. Heidemann, and D. Estrin, "An energy-efficient MAC protocol for wireless sensor networks," in INFOCOM, 2002, pp. 1567-1576.

[11] Sana Ullah *, Bin Shen, S.M. Riazul Islam, Pervez Khan, Shahnaz Saleem and Kyung Sup Kwak, A Study of MAC Protocols for WBANs, Sensors 2010, 10, 128-145; doi:10.3390/s100100128

[12] Kyung Sup Kwak, WBAN MAC: Technology and Proposal, UWB Wireless Communications Research Center Inha University, Incheon, Korea, 2009-04-16

[13] ShihHeng Cheng and ChingYao Huang, Power Model for Wireless Body Area Network, Biomedical Circuits and Systems Conference, 2008. BioCAS 2008. IEEE, pp. 1-4.

[14] COMPARISON OF CSMA BASED MAC PROTOCOLS OF WIRELESS SENSOR NETWORKS, Himanshu Singh and Bhaskar Biswas

[15] S.S. Kulkarni, "TDMA Services for Sensor Networks", Proceedings of 24th International Conference on Distributed Computing Systems Workshops, 23-24 March 2004, pp. 604-09.

[16] Stemm, M., and R. H Katz, "Measuring and reducing energy consumption of network interfaces in hand-held devices", IEICE Transactions on Communications, Special Issue on Mobile Computing, E80-B(8), August 1997, pp.1125-1131.

[17] Chen, B., K. Jamieson, H. Balakrishnan, and R. Morris, "Span: An energy efficient coordination algorithm for topology maintenance in ad hoc wireless networks", ACM Wireless Networks Journal, vol.8 (5), September 2002, pp.481-494.

[18] N. K. Ray and A. K. Turuk, "A Review on Energy Efficient MAC Protocols for Wireless LANs," in *Fourth International Conference on Industrial and Information Systems, ICIIS 2009, Sri Lanka, 2009.*

[19] www.scalablenetworks.com/publications/documentation.

[20] S. Singh and C.S. Raghavendra, "PAMAS: Power Aware Multi-Access protocol with Signaling for Ad Hoc Networks", *ACM Computer Communications Review*, July1998.

[21] Hagen Woesner, adam Wolisz, Power saving mechanism in emerging standards for wireless LANs: the MAC level perspective, IEEE PCS, 2001.

[22] Vivek Jain, Ratnabali Biswas, Dharma P. Agrawal: Energy-Efficient and Reliable Medium Access in Sensor Networks. WOWMOM 2007: 1-8.

[23] V. Rajendran, J. J. Garcia-Luna-Aceves and K. Obraczka, "Energy-Efficient Application-Aware Medium Access for Sensor Networks", IEEE International Conference on Mobile Adhoc and Sensor Systems, November 2005. FLAMA

[24] Salman Faiz Solehria, Sultanullah Jadoon, Medium Access Control Protocol for Wireless Sensor Network – a Survey, International Journal of Video & Image Processing and Network Security IJVIPNS-IJENS Vol: 11 No: 03

[25] H. Takagi and L. Kleinrock, "Throughput Analysis for Persistent CSMA Systems," *IEEE Transactions On Communications*, vol. 33, no. 7, pp. 627–638, July 1985.

[26] P. Karn, "MACA - A New Channel Access Method for Packet Radio," in *9th ARRL Computer Networking Conference*, London, Ontario, Canada, 1990.

[27] A. Woo and D. Culler, "A Transmission Control Scheme for Media Access in Sensor Networks," in *ACM Mobicom*, Rome, Italy, July 2001.

[28] S. Singh and C. S. Raghavendra, "PAMAS - power aware multi-access protocol with signaling for ad hoc networks," *ACM SIGCOMM Computer Communication Review*, vol. 28, no. 3, pp. 1048–1057, 1998

[29] I. C. Society, *802.11 IEEE Standard for Information technology - Telecommunications and information exchange between systems – Local and metropolitan area networks - Specific requirements. Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications*, IEEE Std., 12 June 2007.

[30] Ruizhong Lin, Zhi Wang, and Youxian Sun, Energy Efficient Medium Access Control Protocols for Wireless Sensor Networks and Its State-of-Art, 0-7803-8305-2/04/$20.00 ©2004 IEEE

[31] Shah Murtaza Rashid Al Masud. Article: Study and Analysis of Scientific Scopes and Issues towards Developing an Efficient LECIM. *International Journal of Computer Applications* 74(6):46-56, July 2013. Published by Foundation of Computer Science, New York, USA

[32] S. Singh and C.S. Raghavendra, "PAMAS: Power Aware Multi-Access protocol with Signaling for Ad Hoc Networks", *ACM Computer Communications Review*, July1998.

[33] [13] P. Havinga, G. Smit, "Energy-efficient TDMA medium access control protocol scheduling," in the *Proceedings of the Asian International Mobile Computing Conference (AMOC 2000)*, November 2000.

[34] A. Barroso, U. Roedig, and C. Sreenan, "μ-MAC: an energy-efficient medium access control for wireless sensor networks", Wireless Sensor Networks, 2005. Proceedings of the Second European Workshop on 24 Jan.-2 Feb. 2005 Page(s):70 – 80.

[35] P.C. Nar and E. Cayirci, "PCSMAC: a power controlled sensor-MAC protocol for wireless sensor networks", Wireless Sensor Networks, 2005. Proceedings of the Second European Workshop on 24 Jan.-2 Feb. 2005 Page(s):81 – 92.

[36] C. K. Nguyen and A. Kumar, "An energy-aware medium-access-control protocol with frequent sleeps for wireless sensor networks", Computers and Communications, 2005. ISCC 2005, Proceedings, and 10th IEEE Symposium on 27-25 June 2005 Page(s):386 – 391.

[37] V. Rajendran, J. J. Garcia-Luna-Aceves and K. Obraczka, "Energy-Efficient Application-Aware Medium Access for Sensor Networks", IEEE International Conference on Mobile Adhoc and Sensor Systems, November 2005. FLAMA

[38] Hind Chebbo, Literature Review of Energy Efficient MAC in WSN/BAN, IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs), May, 2008.

[39] Polastre, J.; Hill, J.; Culler, D. Versatile low power media access for wireless sensor networks. In Proceedings of the 2nd International Conference on Embedded Networked Sensor Systems, New York, NY, USA, 2004; pp. 95-107.

[40] Schurgers, C.; Tsiatsis, V.; Srivastava, M.B. STEM: Topology management for energy efficient sensor networks. In Proceedings of Aerospace Conference, Manhattan Beach, CA, USA, 2004; Volume 3, pp. 3-1099–3-1108.

[41] Dam, V.T.; Langendoen. K. An adaptive energy-efficient mac protocol for WSNs. In Proceedings of the 1st ACM Conference on Embedded Networked Sensor Systems (Sen-Sys), Los Angeles, CA, 2003; pp. 171-180.

[42] Khan, N.P.; Boncelet, C. PMAC: Energy efficient medium access control protocol for wireless sensor networks. In Proceedings of IEEE Military Communications Conference, Washington, DC, USA, 2006; pp. 1-5, 23-25.

[43] Lu, G.; Krishnamachari, B.; Raghavendra, C. An Adaptive Energy-Efficient and Low-Latency MAC dor Data Gathering in Sensor Networks. In Proceedings of the 4th International Workshop on

Algorithms for Wireless, Mobile, Ad Hoc and Sensor Networks, Santa Fe, Mexico, 2004.

[44] Rajendran, V.; Garcia-Luna-Aveces, J.J.; Obraczka, K. Energy-efficient, application-aware medium access for sensor networks. In Proceedings of IEEE Mobile Adhoc and Sensor Systems Conference, Washington, DC, USA, 2005; p. 8630.

[45] Heinzelman, W.R.; Chandrakasan, A.; Balakrishnan, H. Energy-efficient communication protocol for wireless microsensor networks. In Proceedings of the 33rd Annual Hawaii International Conference on System Sciences, Maui Kula, HI, USA, 2000.

[46] Younis, O.; Fahmy, S. Heed: A hybrid, energy-efficient, distributed clustering approach for adhoc sensor networks. IEEE Trans. Mob. Comp. 2004, 3, 366-379.

[47] R. Venkateswari, S. Subha Rani, P. Gowtham Reddy: Efficient MAC protocol for Wireless Body Area Nwtworks-A survey, GJCST, Volume 11, Issue 8, Version1.0, May 201, USA.

[48] Index of Bureaus. Available online: http://www.fcc.gov/Bureaus/ (accessed on 16 August 2009).

[49] Niamat Ullah,* Pervez Khan, and Kyung Sup Kwak: A Very Low Power MAC (VLPM) Protocol for Wireless Body Area Networks, Graduate School of Information & Communication Engineering, Inha University, 253 Yonghyun-dong, Nam-gu, Incheon 402-751, Korea.

Improvement of Adaptive Smart Concentric Circular Antenna Array Based Hybrid PSOGSA Optimizer

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***Abstract*—Unlike all recent research which used Concentric Circular Antenna Array (CCAA) based on one beam-former for each single main beam, this research presents a technique to adapt smart CCAA by using only single beam-former for multi main beams based on hybrid PSOGSA. Hybrid PSOGSA is a combining technique between Particle Swarm Optimization and Gravitational Search Algorithm which is applied in the feeding of the smart CCAA to enhance its performance. Phase excitation of the array with a large number of elements is suggested for different scenarios based on hybrid PSOGSA and other algorithms such as PSO and GSA in High Altitude Platform (HAP) application. Simulation results proved that hybrid PSOGSA achieves better performance than other optimizers for excitation of the smart CCAA in all scenarios for different parameters like normalized array factor, fitness values, convergence rate, and directivity.**

Keywords*—*Smart antenna; CCAA; PSOGSA; HAP; and Beam-forming

I. Introduction

Smart antenna was one of the main parts in various communication systems [1-3]. Circular Antenna Array (CAA) [4,5] was considered recently in the latest research because of its ability to steer the radiation pattern more than linear antenna arrays and overcoming the broadside problem. CCAA implements different rings with different radius that are used in most wireless applications such as High Altitude Platform (HAP) and others [6-10].

Particle Swarm Optimization (PSO) in [11] was used in a MIMO system in [12]. Cooperative communication based on one and multi relay was proposed by using PSO in [13,14]. The suggested Gravitational Search Algorithm (GSA) in [15] was used for Direction of Arrival estimation in smart antenna systems and achieved better results than MUSIC and PSO in [16]. Synthesis CCAA was studied by GSA and modified PSO in [17]. GSA was used to control reconfigurable dual-beam for the CCAA and steer null toward SNOI using Linear Constraint Minimum Variance Assisted by different optimization techniques, finally GSA gave the best performance in [18, 19].

Recently, Hybrid Particle Swarm Optimization with Gravitational Search Algorithm (Hybrid PSOGSA) technique was considered as a new optimization technique that showed better performance than standard PSO and GSA in terms of computational speed and fitness values [20,21]. In [22], an algorithm based on collective animal behaviour (CAB) is used for finding the best optimal excitation weights for linear antenna arrays, but in [4,5], hybrid PSOGSA utilizing UCA achieved better results than ULA in terms of studying the directed power in terms of normalized array factor toward the intended direction in addition to direct null to signal Not of interest (SNOI) for different scenarios.

In this paper, unlike all previous research which was based on multi beam-former for multi beams like [17-19,22,23] or small number of elements like [4-5], a novel algorithm using only one beam-former for multi beams that is based on the hybrid PSOGSA technique is utilized for optimal beam-forming using CCAA which implement a greater number of elements up to 121 elements. The main aim based on controlling the complex weights in order to maximize and minimize the beam of the radiation pattern towards the desired user (SOI) or not desired (SNOI) respectively. The paper is organized as follows. In Section II, the optimization model and problem formulation for adaptive beam-forming is suggested. In Section III, hybrid PSOGSA algorithm is proposed. Simulation results and discussions for beam-forming are discussed in Section IV. Finally, Section V explains the conclusions.

II. Optimization Problem Model

CCAA is suggested for Smart antenna, as shown in Figure 1. CCAA with N elements are distributed along M circles of radius r_m and each circle has N_m elements, The Array factor for CCAA can be defined from[7] as shown:

$$\mathrm{AF}(\theta) = \sum_{m=1}^{M} \sum_{n=1}^{N_m} [\cos(\beta * r_m * \cos(\theta - pos_{mn}) - \alpha_{mn}) + j\sin(\beta * r_m * \cos(\theta - pos_{mn}) - \alpha_{mn})] \quad (1)$$

Where λ is the wavelength, the angle between adjacent elements is θ_0, θ is the azimuth angle, $d = 0.5\lambda$ is the space between two adjacent elements, β is the phase shift constant, α_{mn} represents the complex excitation phase of the mn-th element and pos_{mn} is the angular position of the mn-th element. The studying for radiation pattern shows the phase excitation for elements in smart array must minimize the radiation power intensity at certain directions (SNOI) and maximize the main-lobes to other directions (SOI). Our cost function is modified than cost function in [13] where we maximized the total output power toward the desired signal at θ_i and minimized the total output power in the direction of the interfering signals at θ_j and this done by minimizing the fitness function in (2).

$$\text{fitness function} = -\sum_{i=1}^{k} a_i AF(\theta_i) + \sum_{i=1}^{L} b_i AF(\theta_i) \qquad (2)$$

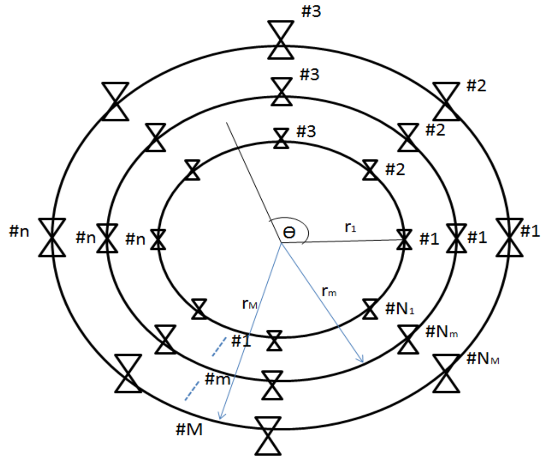

Fig. 1. Structure of the smart CCAA

In this paper, CCAA uses number of elements N=121 for huge application like High altitude Platform (HAP) as shown in [6, 23]. When PSOGSA is compared with other previous algorithms like PSO and GSA according to many factors such as normalized array factor using(1), directivity using (3) as shown in [7] and computational speed with convergence rate for normalized fitness values using (2).

$$D = 4\pi / \int_0^{2\pi} \int_0^{\pi} |AF_n|^2 \; sin\phi \; d\phi \; d\,\theta \qquad (3)$$

Where ϕ elevation angle which is used 900 in our work and θ is azimuth angle.

III. Hybrid Psogsa Optimizer

In this paper, PSO and GSA were combined with a parallel hybridized method not series method and for this reason the hybridization method was called co-evolutionary. On the other hand, the low level combines the functionality of both algorithms. It is heterogeneous because there are two different algorithms that are involved in producing final results. The main idea of hybrid PSOGSA is a combination between capability of local search by GSA and social think the ability by PSO. Velocity is updated as follows from [20,21]:

$$v_i(t+1) = \text{part 1} + \text{part 2} \qquad (4)$$

Where part 1 of the GSA [15] $: w * v_i(t) + C1 * rand * a_i(t)$ and part 2 of the PSO [11] $: C2 * rand * (gbest - x_i(t))$ finally, velocity can be updating by

$$v_i(t+1) = w * v_i(t) + C1 * rand * a_i(t) + C2 * rand * (gbest - x_i(t)) \qquad (5)$$

Every iteration, the positions of agents are updated as follows:

$$x_i(t+1) = x_i(t) + v_i(t+1) \qquad (6)$$

Where gbest is global best position from PSO, w is a weighting factor, rand is a random number, C1 and C2 are constant, $v_i(t)$ is the velocity of particlei at iteration t and $a_i(t)$ is the acceleration of agent i at iteration t. all these parameters are taken from PSO and GSA algorithm [20, 21]. Finally Hybrid PSOGSA procedures are shown in Figure 2.

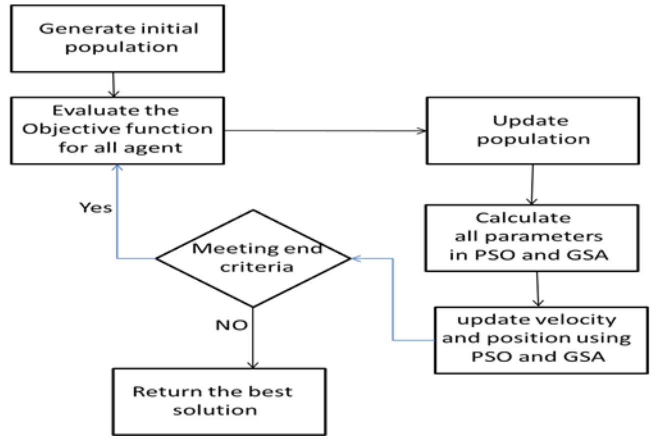

Fig. 2. Flow chart of procedures for hybrid PSOGSA optimizer

As shown in Figure 2, the first step is responsible for all agents are randomly initialized. Each agent is considered as a candidate solution. As can be seen in the second step, after initialization, evaluate the fitness function based on equation (2). At the third and fourth step, gravitational force, gravitational constant, resultant forces among agents are calculated, and the accelerations of particles are defined from [20, 21]. In each iteration, the best solution so far (gbest) must be updated. After calculating the accelerations and with updating the best solution so far, the velocities and the positions of all agents can be updated from [20, 21] at the fifth step. Finally, after the agents are updated. The process of updating velocities and positions will be stopped by meeting an end criterion.

IV. Simulation and Discussion Results

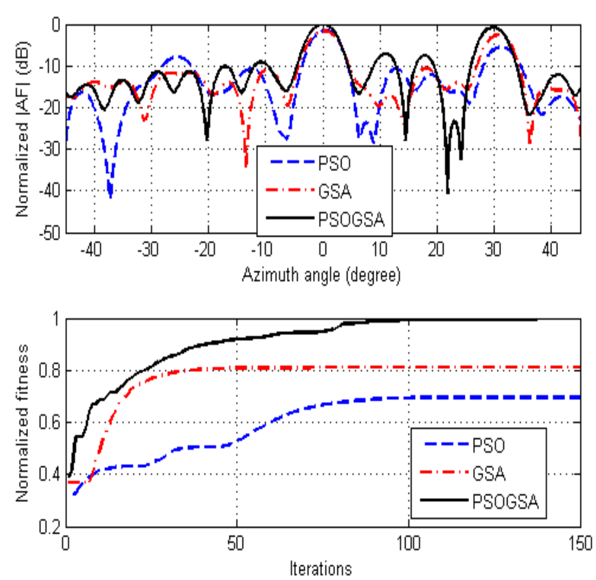

Fig. 3. The first scenario for normalized array factor versus azimuth angle and fitness functions versus iteration using Hybrid PSOGSA, PSO and GSA based on CCAA topology

MATLAB package is used for evaluating the above analysis. In this section, ability of adaptive beam-forming based on hybrid PSOGSA technique using CCAA is studied. All algorithms are employed with a population size of 30 and 150 iterations which represent a small number of iterations. Figures 3,4,5,6, and 7 show comparison of PSOGSA with GSA and PSO using CCAA topology for many scenarios in terms of radiation pattern, convergence curve and computation time, in order to compute directivity. The work implemented 121 elements in all scenarios for HAP application.

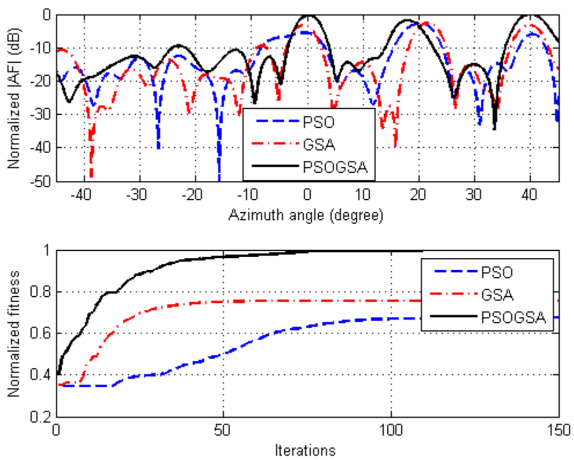

Fig. 4. The second scenario for normalized array factor versus azimuth angle and fitness functions versus iteration using Hybrid PSOGSA, PSO and GSA based on CCAA topology

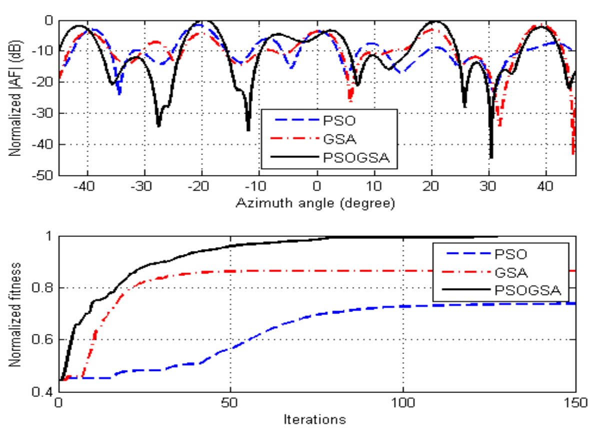

Fig. 5. The third scenario for normalized array factor versus azimuth angle and fitness functions versus iteration using Hybrid PSOGSA, PSO and GSA based on CCAA topology

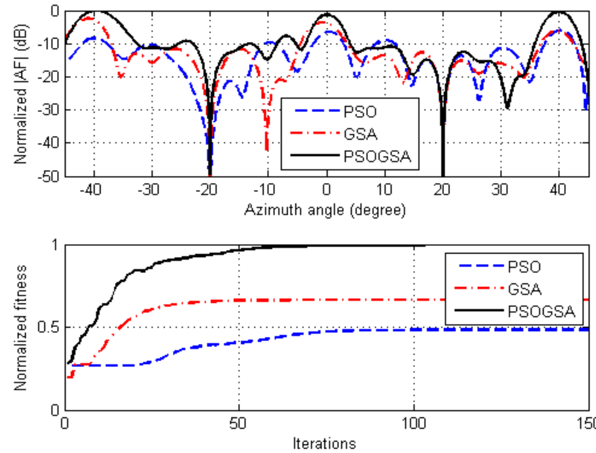

Fig. 6. The fourth scenario for normalized array factor versus azimuth angle and fitness functions versus iteration using Hybrid PSOGSA, PSO and GSA based on CCAA topology

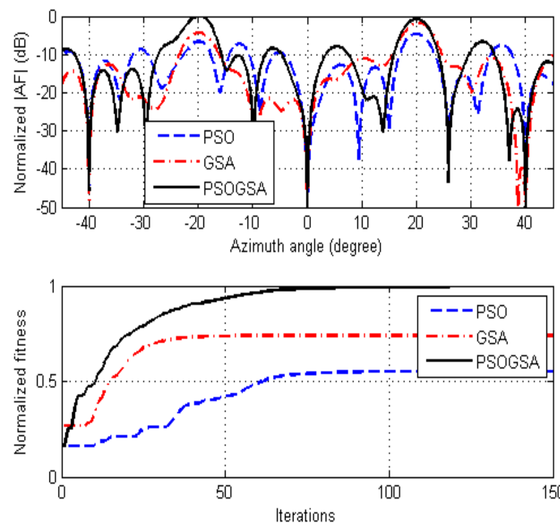

Fig. 7. The fifth scenario for normalized array factor versus azimuth angle and fitness functions versus iteration using Hybrid PSOGSA, PSO and GSA based on CCAA topology

All scenarios can be discussed in Tables 1 and 2. Table 1 indicates that hybrid PSOGSA in general outperforms PSO and GSA. The hybrid PSOGSA is better than PSO and GSA in all scenarios by range from -2.8 to -6.65 and from -1.4 to -3.85 respectively in terms of averages normalized array factor in dB.

TABLE I. THE CORRESPONDING AVERAGE NORMALIZED |AF| VALUES AT THE SOI AND SNOI DIRECTIONS FOR DIFFERENT SCENARIOS BASED ON CCAA TOPOLOGY

Scenarios	Desired Angles	Interferer Angles	Average Normalized array factor (dB)					
			PSO		*GSA*		PSOGSA	
			Major	Null	Major	Null	Major	null
1	[0 30]	----	-3.8	------	-2.2	------	-0.35	------
2	[0 20 40]	----	-4.7	------	-3.5	------	-1.2	------
3	[-40 -20 0 20 40]	----	-5	------	-3.6	------	-2.2	------
4	[-40 0 40]	[-20 20]	-7	>-40	-4.2	>-40	-0.35	>-40
5	[-20 20]	[-40 0 40]	-5.5	>-40	-3	>-40	-0.35	>-40

On the other hand, from table 2, simulation results have shown tremendous improvement over the previous work done using standard PSO and GSA in terms of directivity and convergence speed for normalized fitness values. PSOGSA is better than PSO and GSA by 25%–50% and 15%–30%, respectively in terms of convergence percentage at the end of iteration. It was shown that PSOGSA achieved improvement over GSA and PSO by 1%–70% nearly in terms of directivity. The only disadvantage in PSOGSA is computational time. Still, all algorithms have the ability to produce null toward SNOI by more than -40 dB at scenario #4 and #5.

TABLE II. THE CORRESPONDING NORMALIZED CONVERGENCE PERCENTAGE AT THE END OF ITERATIONS, THE DIRECTIVITY VALUE AT THE MAX SOI DIRECTIONS AND COMPUTATIONAL TIME FOR DIFFERENT SCENARIOS BASED ON CCAA TOPOLOGY

Scenarios	Normalized Convergence percentage (nearly) %			Directivity (dimensionless)			computational time in sec using Lenovo core i7 4702MQ RAM 8 G		
	PSO	*GSA*	*PSO GSA*	*PSO*	*GSA*	*PSO GSA*	*PSO*	*GSA*	*PSO GSA*
1	70	80	100	15.63	16.4	17.4	1	0.5	1.5
2	65	75	100	9.680	11.7	12.5	1	0.5	1.3
3	75	85	100	7.975	9.40	9.52	1.7	0.9	2
4	50	70	100	8.008	10.7	10.8	1.7	0.9	2.1
5	55	75	100	5.665	14.4	14.9	1.6	0.8	1.9

V. CONCLUSION

In this paper, a hybrid PSOGSA technique is implemented only on one beam-former for multi-beams smart antenna systems based on CCAA to improve the capability of smart beam-former in wireless communication systems. It is clear from our optimization model using CCAA, simulation results have shown tremendous improvement over the previous work done using standard PSO and GSA in terms of normalized array factor by range from -2.8 to -6.65 and from -1.4 to -3.85 respectively, directivity by range from 1% to 70%, and convergence speed for normalized fitness values by range from 25% to 50% dB and from 15% to 30%, respectively. However, simulation results and discussions proved the ability of our technique to deal with a big set of simultaneously incident and interfere angles. It was found that hybrid PSOGSA based on CCAA is the best powerful optimizer for smart beam-forming applications and better than GSA and PSO on average for several scenarios.

REFERENCES

[1] Ahmed Magdy, S. Sayed, K.R.Mahmoud , "Modified Cooperative Access with Relay's Data Protocol using smart antenna," Journal of Engineering Sciences, Assiut University, Faculty of Engineering, Vol. 41, No. 6, November, 2013.

[1] Ahmed Magdy, K. R. Mahmoud, S. Sayed, and I. I. Ibrahim, "Modified Cooperative Access with Relay's Data (MCARD)," Production and hosting by Elsevier and sciencedirect B.V. on behalf of Faculty of Engineering, Alexandria University, Volume 53, Issue 1, Pages 33–40, March 2014.

[2] GhouseBasha, T.S.; Aloysius, G.; Rajakumar, B.R.; Giri Prasad, M.N.; Sridevi, P.V., "A constructive smart antenna beam-forming technique with spatial diversity," in Microwaves, Antennas & Propagation, IET , vol.6, no.7, pp.773-780, May 16 2012

[3] Ahmed Magdy, Osama M. El-Ghandour, and Hesham F. A. Hamed, "Performance Enhancement for Adaptive Beam-Forming Application Based Hybrid PSOGSA Algorithm," Journal of Electromagnetic Analysis and Application, 7, 126-133, 2015.

[4] S. S. S. CHAKRAVARTHY VEDULA, S. R. CHOWDARY PALADUGA, AND M. RAO PRITHVI, "SYNTHESIS OF CIRCULAR ARRAY ANTENNA FOR SIDELOBE LEVEL AND APERTURE SIZE CONTROL USING FLOWER POLLINATION ALGORITHM,"INTERNATIONAL JOURNAL OF ANTENNAS AND PROPAGATION, VOL. 2015, PP. 1–9, 2015

[5] Sultan Aljahdali, " Enhancing the Capacity of Stratospheric Cellular Networks Using Adaptive ArrayTechniques," I. J. Computer Network and Information Security, 2013, 6, 1-10, Published Online May 2013

[6] D. Manda1, V.P.Roy, A. Chattrejee, and A. K. Bhattacharjee," Side Lobe Reduction of Concentric Thinned Antenna Array Using Evolutionary Algorithms," IOSR Journal of Electrical and Electronics Engineering, Volume 9, Issue 3 Ver. III, PP 43-49 (May – Jun. 2014).

[7] S. Pal, A. Basak, S. Das, A. Abraham and I. Zelinka, "Concentric Circular Antenna Array synthesis using a differential Invasive Weed Optimization algorithm," Soft Computing and Pattern Recognition (SoCPaR), 2010 International Conference of, Paris, 2010, pp. 395-400.

[8] K. Rajesh Kumar, S. Aruna, and K. SrinivasaNaik," Side Lobe Reduction of a Concentric Circular Antenna Array using Genetic Algorithm (GA) and Particle Swarm Optimization (PSO)," International Journal of Engineering and Innovative Technology (IJEIT), Volume 4, Issue 5, November 2014

[9] D. Mandal, R. Kar and S. P. Ghoshal, "Thinned concentric circular array antenna synthesis using Particle Swarm Optimization with Constriction Factor and Inertia Weight Approach," Recent Trends in Information Systems (ReTIS), 2011 International Conference on, Kolkata, 2011, pp. 77-81.

[10] Kennedy, J. and R. Eberhart, "Particle swarm optimization," IEEE International Conference on Neural Networks, Vol. 4, 1942-1948, Perth, Australia, 1995.

[11] Ho, M.-H.; Chiu, C.-C.; Liao, S.-H., "Optimisation of channel capacity for multiple-input multiple-output smart antenna using a particle swarm optimiser," in Communications, IET , vol.6, no.16, pp.2645-2653, November 6 2012.

[12] Ahmed Magdy, K. R. Mahmoud, and S. Sayed, "Cooperative Communications Based Smart Antenna Systems Using PSO Algorithm," PIERS Proceedings, Stockholm, Sweden, Aug. 12-15, pp.600-615, 2013.

[13] Ahmed Magdy, K. R. Mahmoud, S. Sayed, and I. I. Ibrahim, "Smart Circular Antenna Array Based Cooperative Communications using Optimization Technique," Journal of Engineering Sciences, Assiut University, Faculty of Engineering, Vol. 41, No. 5, September, 2013.

[14] Rashedi, E., H. Nezamabadi-Pour, and S. Saryazdi, "GSA: A gravitational search algorithm," Information Sciences, Vol. 179, No. 13, 2232-2248, 2009.

[15] Ahmed Magdy, K. R. Mahmoud, S. G. Abdel-Gawad, and I. I. Ibrahim, "Direction of Arrival Estimation Based on Maximum Likelihood Criteria Using Gravitational Search Algorithm," PIERS Proceedings, Taipei, March 25-28,pp. 1162-1167, 2013.

[16] Chatterjee, A., G. K. Mahanti, and N. N. Pathak, "Comparative performance of gravitational search algorithm and modified particle swarm optimization algorithm for synthesis of thinned scanned concentric ring array antenna," Progress In Electromagnetics Research B, Vol. 25, 331-348, 2010.

[17] Chatterjee, A., G. K. Mahanti, and P. R. S. Mahapatra, "Design of fully digital controlled reconfigurable dual-beam concentric ring array antenna using gravitational search algorithm,"Progress In Electromagnetics Research C, Vol. 18, 59-72, 2011.

[18] SoodabehDarzi, TiongSiehKiong, Mohammad Tariqul Islam, Mahamod Ismail, SalehinKibria, and Balasem Salem, "Null Steering of Adaptive Beamforming Using Linear Constraint Minimum Variance Assisted by Particle Swarm Optimization, Dynamic Mutated Artificial Immune System, and Gravitational Search Algorithm," The Scientific World Journal, vol. 2014, Article ID 724639, 10 pages, 2014.

[19] SeyedaliMirjalili, and SitiZaitonMohdHashim, "A New Hybrid PSOGSA Algorithm for Function Optimization," International Conference on Computer and Information Application, ICCIA, IEEE 2010.

[20] BinjieGu and Feng Pan, "MODIFIED GRAVITATIONAL SEARCH ALGORITHM WITH PARTICLE MEMORY ABILITY AND ITS APPLICATION," International Journal of Innovative Computing, Information and Control, Volume 9, Number 11, November 2013.

[21] Gopi Ram, Durbadal Mandal, RajibKar, and Sakti Prasad Ghoshal, " Optimized Hyper Beamforming of Linear Antenna Arrays Using Collective Animal Behaviour," The ScientificWorld Journal, Article ID 982017, 13 pages, Volume 2013.

[22] Yasser Albagory, "Flat-Top Ring-Shaped Cell Design for High-Altitude Platform Communications," I. J. Computer Network and Information Security, 2013, 7, 51-57, Published Online June 2013.

[23] C.A. Balanis, Antenna theory: Analysis and design,3rd ed., Wiley, New York, 2005.

Optimized Image Scaling Using DWT and Different Interpolation Techniques

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***Abstract*—Discrete Wavelet Transform (DWT) has gained much limelight in the past years. Wavelet Transform has precedence over Discrete Fourier Transform and Discrete Cosine Transform because they capture the frequency as well as spatial information of a signal. In this paper DWT has been used for image scaling purpose. To achieve higher visual quality image, DWT is applied on the gray scale image using a downscaling technique. The original image is recovered using IDWT by employing different interpolation techniques for upscaling. In this paper interpolation techniques used are: Nearest Neighbor, Bilinear and Bicubic. Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) is calculated for quantifying interpolated image effectiveness. Results show that the reconstructed image is better when using a combination of DWT and Bicubic interpolation.**

Keywords—Bilinear Interpolation; Bicubic Interpolation; Discrete Wavelet Transform Image Scaling

I. Introduction

In digital imaging, image scaling technique has wide range of applications from consumer electronics to medical field [1]. In image scaling, tradeoff is made between efficiency, smoothness and sharpness. Image can be scaled in two ways: up scaling and down scaling. As the name suggests, up scaling involves enlarging the image to fit the desired criteria. Upscaling is achieved by highlighting interesting features of the image. In case of down scaling amount of data required to represent the digital image is reduced. Down scaling is analogous to image compression.

The process of interpolation is one of the fundamental processes in image processing. In image interpolation discrete data, within a known range of abscissa, is represented in the form of continuous data [2]. In interpolation values of the functions that lay at the position between samples is determined, this is attained by fitting a continuous function through discrete input samples. The quality of image depends on the interpolation technique employed. There are two categories of interpolation technique: deterministic and statistical. In deterministic technique, certain variability is assumed between sample points. In statistical interpolation, estimation error is minimized to approximate the signal. Nearest neighbor, bilinear interpolation and bicubic interpolation are commonly used interpolation techniques. Nearest neighbor is the simplest technique but in scaled image the effects of blocking and aliasing are present. Bilinear interpolation is commonly employed technique in which horizontal and vertical directions are linearly interpolated to obtain target pixels [3]. In bicubic interpolation data points are interpolated on a two dimensional regular grid and the scaled image has much smoother results as compared to nearest neighbor and bilinear interpolation.

The primary concept behind wavelets is to evaluate signal (image) at diverse scales or resolutions, this is known as multi-resolution. Temporal resolution is the competitive advantage of wavelet transform over Fourier transform since wavelet transform captures both frequency and location information (location in time).A wavelet family can be constructed from the mother wavelet. Unlike windowed Fourier analysis, a mother wavelet can change the size of widow by stretching or compressing. Due to this outstanding feature of wavelets, approximate and detail image can be attained, where approximate image of the signal is attained by large wavelets, while smaller wavelets give the detail information of the image. Therefore, by different sizes of windows, both high-frequency and low-frequency components of a signal can be adopted by the wavelets. Any little alter in the wavelet representation produces a corresponding little alter in the original signal, which means that local errors will not have an effect on the entire transform. The wavelets are favored for non-stationary signals, such as very concise signals and signals which have interesting components at diverse scales [4].

In this paper algorithm is proposed to interpolate image based on Discrete Wavelet Transform (DWT). Interpolated image is computed by first down sampling and then up-sampling. Thereupon original image and interpolated image are compared through image quality measures. In the results it is shown that in order to achieve image of lower resolution, by employing diverse interpolation techniques, quality of image is affected.

II. Literature Review

The technique of image interpolation is as old as image processing. Initially, linear interpolation or nearest neighbor interpolation techniques were implemented for resampling an image. In late 1940's when Shannon presented the information theory, the interpolation function was sinc function. Nevertheless, sinc function which is ideal interpolator has an infinite response, something which is not preferred for a local interpolation since local interpolation has finite impulse response. From statistical approach it has been suggested to approximate sinc function by using Lagrange polynomial. This concept is present in many numerical analysis based textbooks [5]. Various spline functions families have been used due to their numerical efficiency. In literature, at some places B-splines are mentioned as cubic splines [6], cubic interpolation refers as cubic splines [7], high-resolution spline interpolation [8] and bi-cubic spline interpolation [9]. Parker, Troxel and Kenyon published their very first paper 1983, entitled "Comparison of Interpolation Methods", which was shortly followed by a analogous research put forward in 1988 by Maeland [10]. Moreover, prior effort of Keys, as well as Hou and Andrews, also shows the research done on the comparison between local and global interpolation [11], [12]. Parker et al. researched that the resampled image can have much better quality when cubic interpolation is used rather than nearest neighbor or B-spline interpolation, but at the expense of increased computational complexity. In order to avoid further continuation of mistaken belief, which has emerged over and over again in the literature, instead of interpolation it is preferred to address B-spline technique as B-spline approximation. Since 1990s, wavelet transforms are being productively used in image processing because of admissibility and regularity conditions which are two main properties of wavelets [13]. Image compression based on wavelet approach has proved to be an proficient and simplest method for image scaling. The principle objective behind wavelets is to calculate the high resolution details of the image. Previously, some prediction methods were proposed. Huang and Chang's research [14] make use of multilayer perceptron (MLP) from neural networks; Chang and Carey et al [15],[16] proposed Mallat's wavelet transform modulus maxima theory method [16]. Although Kinebuchi et al. [18] make use of Hidden Markov Trees (HMT) in order to predict coefficients present at higher scales, however, the drawback for HMT was the requirement of computationally extensive training procedure for parameter estimation. Therefore it was the need to introduce HMT-based methods which do not require any training data set [19]. A scheme proposed by Zhu et al. [20] makes use of statistical estimation. Wavelet analysis is an exciting novel method for solving difficult tasks in physics, mathematics and engineering, with modern application as diverse as data compression, wave propagation, image and signal processing, the detection of aircraft, pattern recognition, and submarines, computer graphics and other medical image technologies[21],[22],[23], [24] [25], [26]. Wavelet transform provides as efficient way for performing image fusion at multi scales with several advantages such as locality, multi resolution analysis, energy compaction and de–correlation [27]. Due to the admirable approximation ability of wavelet transform, image interpolation based on wavelets approach, performs well at the non-edge regions [28].

III. Discrete Wavelet Transform

Discrete Wavelet Transform (DWT), as suggested by the name is a wavelet transform in which wavelets are discretely sampled by multi-resolution analysis. The multi resolution decomposition procedure is the of distribution of a signal onto a set of wavelet basis functions.

There are different DWT schemes which can be used for different sophisticated tasks. The most simple and most common DWT scheme is "Haar" wavelet. Haar wavelet can't be differentiated because it is not continuous, which is a technical disadvantage of Haar wavelet [29].Application of DWT in 1-dimensional signal corresponds to 1-dimensional filter in each dimension [30]. While in case of images which are referred as 2-dimesional signal; application of DWT corresponds to 2D filter image processing in two dimension [31].Multi-resolution analysis decomposes the image into four non-overlapping subbands which contain approximation and detail coefficients. These sub-bands namely are LL_1, LH_1, HL_1 and HH_1[32]. In the proposed paper, these coefficients are computed using 5/3 Integer Wavelet. The advantage of using 5/3 filter is that it can be implemented in hardware using shift and odd operations.

The analysis low- and high-pass 5/3 Wavelet filters are:

$$\{h_{-2}, h_{-1}, h_0, h_1, h_2\}=\{\frac{-1}{8},\frac{1}{4},\frac{3}{4},\frac{1}{4},\frac{1}{8}\} \quad (1)$$

$$\{g_{-1}, g_0, g_1\} = \{\frac{-1}{2},\frac{1}{1},\frac{1}{2}\} \quad (2)$$

Suppose there is a one dimensional input signal s(t). In first level, s(t) by passing through high and low pass filter is decomposed into approximation and detail coefficients. In second level of decomposition, approximation coefficients obtained from first level is further decomposed into approximation and detail coefficients. Mathematically,

$$s(t)= \sum_k pA_0(k)\varphi_{j,k}(t)=\sum_k pA_1(k)\varphi_{j-1,k}(t) + \sum_k pD_1(k)\omega_{j-1,k}(t) \quad (3)$$

Approximation coefficients, 'pA_0' are at scale index j. However approximation coefficients pA_1 and detail coefficients 'pD_1' are at scale index j-1. '$\varphi_{j,k}$'and '$\omega_{j,k}$' are known as wavelet bases. Input signal is decomposed by using these wavelet bases. There exist orthogonality between wavelets and scale at each index level, coefficients 'pA_1' and 'pD_1' can be expressed in following equation:

$$pA_1 = \sum_n h_0\,(m-2k)pA_0(m) \quad (4)$$

$$pD_1 = \sum_n h_1(m-2k)pA_0(m) \quad (5)$$

The approximation sub-band LL_1; decomposed further in order to obtain next coarser scale of wavelet coefficients, until the desired scale "N" is obtained [34].

In above equation after convolution, it is downsample by the factor of 2. h_0 is scaling and h_1 is wavelet filter. The decomposition of a signal is not permanent. The decomposition of approximation and a detail can be inversed by using inverse transform. Inverse transform can be shown mathematically by similar expression but upsampling by a factor of 2will be used instead of down sampling and quadrature mirror filter (QMF).

A. Analysis

Image has two dimensional representations. Therefore, when dealing with image as an input signal we have to expand analysis and reconstruction in two dimensions.

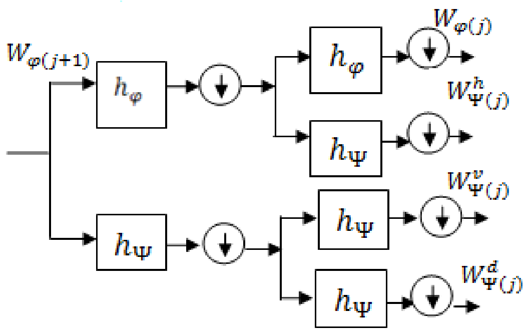

Fig. 1. Analysis Block Diagram

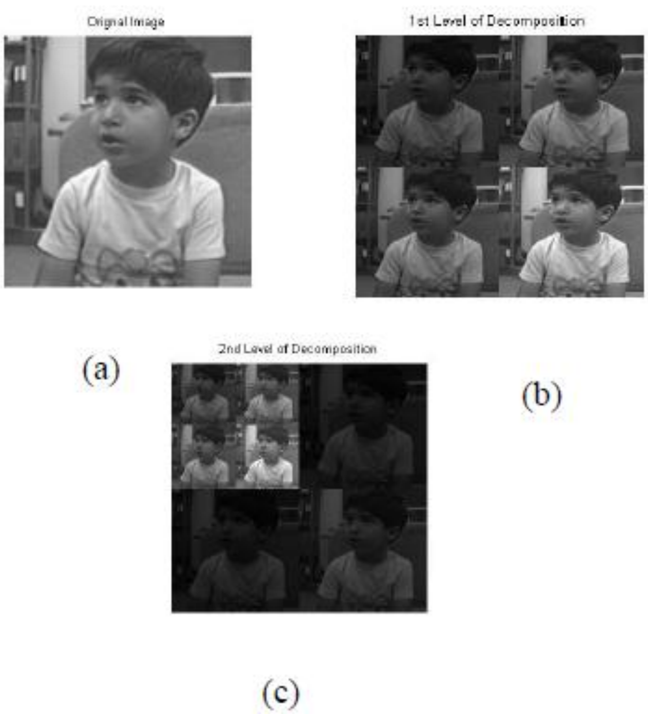

Fig. 2. (a) Original Image (b) First level of decomposition (c) Second level of decomposition

When dealing with images, the image is decomposed into two subbands as shown in Fig.1: when image is passed through low pass filter the respective subband is low-pass filter version and when image is passed through high pass filter it is high-pass filter version. In doing so, spatial bandwidth gets half into each of subband. Such decomposition by passing the signal through low- and high-pass filter is 1D convolution followed by subsampling by factor 2 along rows and columns of image. Subsampling by the factor of 2; means that out of two consecutive samples, one of them was picked and the other was discarded. In the analysis case for one level decomposition, when downsample by the factor of 2 along row and column means that '$W_{\varphi(j)}$' contains 1/4th of the total number of image samples. In above Fig.1, ***h*** symbolized horizontal coefficients, ***v*** vertical coefficients and ***d*** detail coefficients. Fig.2. shows the decomposition of original image up to second level of decomposition.

B. Synthesis

Synthesis process reconstructs the original image. The subbands are first upscaled and then convolved with the respective filters. These upscaled convolved subbands are then added for original image reconstruction. This process is shown in Fig.3.

The synthesis low- and high-pass filter coefficients:

$$\{h_{-1},h_0,h_1\}=\{\tfrac{1}{2},1,\tfrac{1}{2}\} \quad (6)$$

$$\{g_{-2}, g_{-1}, g_0, g_1, g_2\} = \{\tfrac{-1}{8},\tfrac{-1}{4},\tfrac{3}{4},\tfrac{-1}{4},\tfrac{-1}{8}\} \quad (7)$$

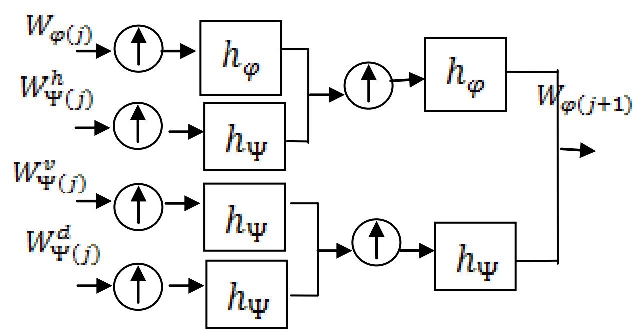

Fig. 3. Synthesis Block Diagram

Research shows that analysis filter for image minimization and reconstruction filters can be employed for image intensification. Due to their design and fractal nature wavelet filters have good interpolation properties.

For the proposed algorithm, x_j was presumed to be the original image. Using lowpass filter analysis, it as downscaled by the factor of 2. Approximation of an original image, can be represented by lowpass filter coefficients x_{j+1}. Since it is downsample by the factor of two it has height and width half of the original image. If analysis filter is normalized by Euclidean distance and the image is convolved with single normalized value instead of whole analysis filter, a better image is obtained. Moreover, in order to get better results the normalized value was multiplied with the factor of 3.Multiplying by the factor of 3 adjust the grayscale values.

Afterwards, lowpass coefficients x_{j-1} , should be upscale.

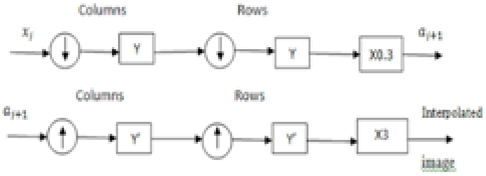

Fig. 4. Proposed Method

In Fig. Symbolize downsampling. Symbolize Upsampling.

“X” is to be multiplied by the corresponding normalized factor calculated. “Y” is analysis filters and “Y’” represents synthesis filters.

IV. Interpolation Techniques

The original image is used for the evaluation of multiple interpolation techniques. Initially, the original image is downscaled which results in low resolution image. In order to magnify the image, interpolation is needed. In the proposed paper, different interpolation techniques were used and the resultant interpolated image was compared with the original image. In the literature, different approaches are discussed; some authors [35] have proposed using the same interpolation technique for downscaling as well as for upscaling and then comparing original image and interpolated image. Whereas, according to other approach [36] different interpolation techniques are used for upscaling and downscaling. Instead of scaling some authors have recommended image rotation [37]. On comparison of original image and interpolated images, results show that quality measures depend mostly on the downsampling method. Upsampling can also affect the results, it too can improve or degrade the results, but it doesn’t have much effect as compared to downsampling.

In the domain of digital signal processing, interpolation is defined as the method of converting a sampled digital signal, by using a variety of digital filter methods, to signal with higher sampling rate.

In the present research, the method used for downsampling was the same, whereas upsampling was achieved by using different interpolation techniques. Interpolation techniques for upsampling were used since upsampling by interesting zeros between original samples adds undesired spectral images which are centered on multiples of the original sampling rate. In order to avoid dreadful results interpolation was used. Nearest Neighbor, Bilinear and Bicubic interpolation techniques are used for upscaling.

V. Qunatifying Interpolation Effectiveness

When image is interpolated, one of the several distortion or quality metrics can be applied to quantify the degree to which the interpolated image matches the test image. Some of quality metric measures are:

A. *Signal to Noise Ratio(SNR)*

SNR is the ratio between the average power of the signal and that of corrupting noise. Mathematically;

$$SNR = 10log_{10} \frac{\sum_i \sum_j a_{i,j}^2}{\sum_i \sum_j (a_{i,j} - b_{i.j})^2} \quad (8)$$

In the above expression, ‘$a_{i,j}$’are pixels from test image and ‘$b_{i.j}$’ are pixels of resultant interpolated image respectively.

B. *Mean Square Error (MSE)*

MSE is mean square error, which is given as;

$$MSE = \frac{1}{mn} \sum_{i=1}^{m} \sum_{j=1}^{n} (x_{i,j} - y_{i,j})^2 \quad (9)$$

Where; ‘m’ and ‘n’ describe height and width of the image.

C. *Structure Similarity Index Measure (SSIM)*

SSIM is used to evaluate the similarity between the tested and reconstructed image. Where MSE or PSNR estimate absolute errors, SSIM considers image degradation as perceived change in structural information. Mathematically;

$$\text{SSIM} = \frac{(2\,\mu_x \mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} (10)$$

Where:

$\boldsymbol{\mu_x}$; average of x,$\boldsymbol{\mu_y}$; average of y,$\boldsymbol{\sigma_x^2}$; variance of x,$\boldsymbol{\sigma_y^2}$; variance of y,$\boldsymbol{\sigma_{xy}}$; covariance of x and y,$\boldsymbol{c_1} = (\boldsymbol{k_1 L})2$,$\boldsymbol{c_2} = (\boldsymbol{k_2 L})2$ are the two variables used to stable the division with weak denominator, $\boldsymbol{L}$; dynamic range of pixel values.By default $\boldsymbol{k_1}$= 0.01 and $\boldsymbol{k_2}$= 0.03

VI. Results and Calculations

A. *Traditional Interpolation Techniques Result*

a) Nearest Neighbor

In this technique simply replicate the value from neighboring pixels. The Nearest Neighbor algorithm is the simplification of pixel replication and decimation. Fractional resizing, i.e. to resize image such that it has m/n of the pixels per column and m/n of the rows in the original (m and n are both integers) is also included in nearest neighbor technique. When applied on SINAN image the reconstructed image after using nearest neighbor technique is shown in Fig.5 (a).

b) Bilinear Interpolation

Bilinear Interpolation calculates new values for the pixels that have middle values between the original pixels. The result of bilinear interpolation is smoother but somewhat blurry. The pictorial functioning along with mathematical derivation of this scheme is depicted in Fig.5(b).

c) Bicubic Interpolation

In image processing, when speed is not an issue for image resampling, bicubic interpolation is often favored over bilinear or nearest neighbor interpolation techniques. Unlike bilinear interpolation which takes 4 pixels (2x2) into account, bicubic interpolation considers 16 pixels (4x4). Therefore, bicubic interpolation resampled images gives smoother results and have few interpolation artifacts. Image reconstructed by upscaling using Bicubic Interpolation technique is shown in Fig.5(c).

Image quality measure metrics SNR, MSE, PSNR and SSIM were also calculated as shown in TABLE I.

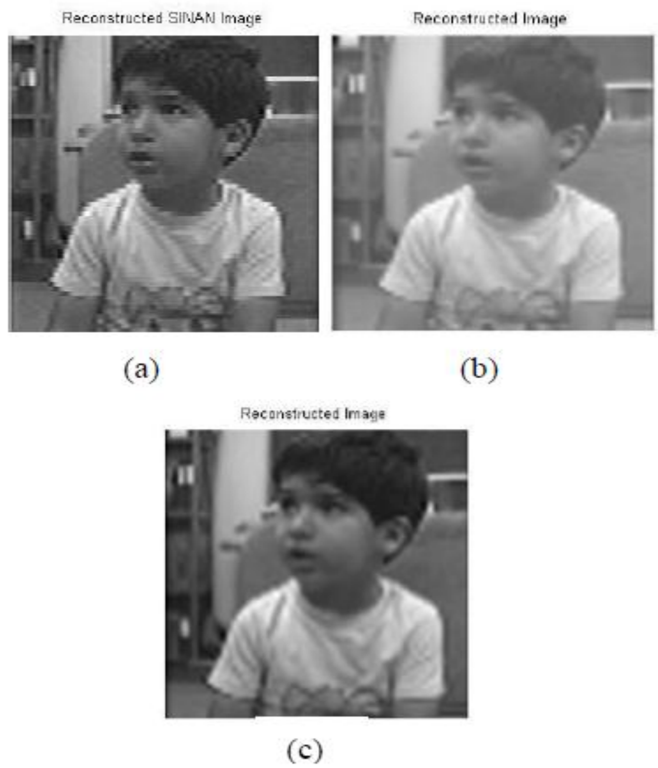

Fig. 5. (a) Nearest Neighbor (b) Bilinear (c) Bicubic Interpolation

B. *Proposed Algorithm Results*

The quality of reconstructed image was better when proposed algorithm was used. Results are shown in Fig.6.

Fig.6(a) shows the image reconstructed by using *nearest neighbor* technique for upsampling. It has much better quality as compared to image reconstructed earlier since that one has blocky affects.

Fig.6 (b) has image quality much better as compared to Fig.5. (b). It has defined edges whereas in Fig.5.(b) edges were not that much sharp.

Fig. 6 (c) visually don't show much difference as compared to Fig. 5 (c) but the image quality measure calculations shown in TABLE II show that the image reconstructed through proposed algorithm has "good" PSNR as compared to the image reconstructed earlier.

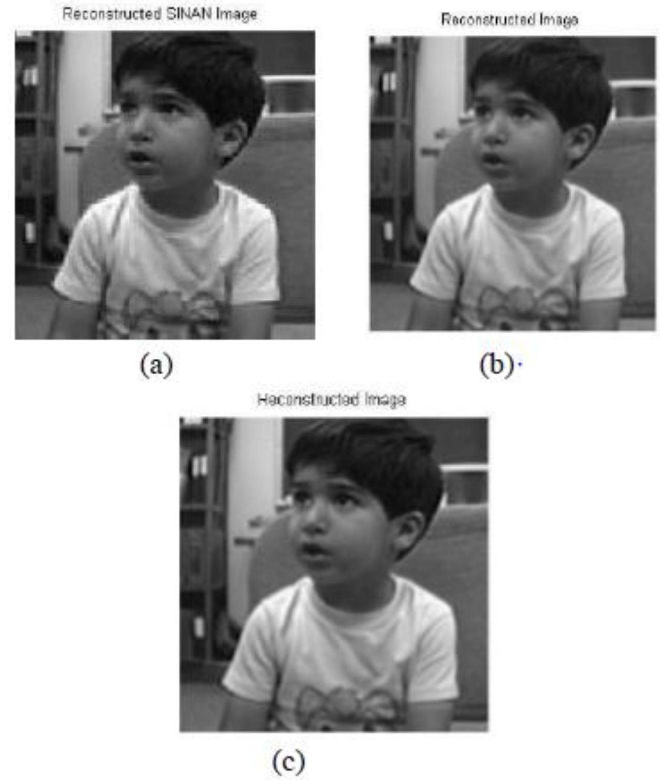

Fig. 6. (a) Nearest Neighbor (b) Bilinear (c) Bicubic Interpolation

These calculations support our algorithm. Reconstructed image quality is much better when proposed algorithm is used, as compared to traditional technique or previous algorithm. The proposed algorithm has more PSNR. The reconstructed images using proposed algorithm have less artifacts or blurring.

TABLE I. INTERPOLATION EFFECTIVENESS MEASURE VIA TRADITIONAL APPROACH

Interpolation Techniques	***Mean Square Error (MSE)***	***Peak Signal to Noise Ratio (PSNR)***	***Signal to Noise Ratio (SNR)***	***SSIM***
Nearest Neighbor	3.6362	45.6064	4.3354	0.0008
Bilinear	3.7644	65.7570	23.9636	0.0070
Bicubic	3.9790	65.9978	24.1771	0.0023

TABLE II. PROPOSED ALGORITHM INTERPOLATION EFFECTIVENESS MEASURE

Interpolation Techniques	*Mean Square Error (MSE)*	*Peak Signal to Noise Ratio (PSNR)*	*Signal to Noise Ratio (SNR)*	*SSIM*
Nearest Neighbor	7.2155	48.5826	7.24	0.0030
Bilinear	1.4867	61.7223	20.2524	0.0351
Bicubic	1.5131	61.7986	20.3116	0.0165

VII. CONCLUSION AND FUTURE WORK

In this paper it is an efficient method to scale an image using discrete wavelet transform is proposed and the results proved the accuracy and efficiency of proposed methodology. It was observed how different interpolation techniques used in downscaling influence the reconstructed image. When nearest neighbor interpolation techniques used for downscaling the reconstructed image has artifact. Bilinear has much better results as compared to nearest neighbor. Moreover, Bicubic Interpolation technique gave the best reconstructed image. The method proposed for wavelet downscaling in this paper give appreciably better results for all quality measures metrics and upscaling method in comparison with traditional interpolation methods.

In future, different interpolation techniques can be used for upscaling as well. These upscaled and transformed images can be used with different downscaled techniques to reconstruct the test image. Moreover, different quality measure such as MSE, PSNR and SNR can be calculated to support the proposed methods. In the proposed method multiplication and division was done by the factor of 0.5, in future any other factor can be used too, to observe the effect they have on reconstructed image. We have used an image "SINAN", we can perform the same method on multiple images, i.e. Text image, medical image and animal image too, and compared the image quality measures for all these images.

REFERENCES

[1] Shih-Lun, "*VLSI implementation of a low-cost high-quality image scaling processor*", IEEE transaction. Circuit System II, Exp.Breifs, vol.60, No.1,pp.31-35,Jan 2013.

[2] THÉVENAZ, P., BLU, T., UNSER, M. Image interpolation and resampling. In Handbook of Medical Imaging, Processing and Analysis, I.N. Bankman, Ed., Academic Press, San Diego CA, USA, pp. 393-420,2000.

[3] Jensen.K and Anastassiou.D, "*Subpixel edge localization and the interpolation of still images*." IEEE transaction.Image Process, vol.4, no.3, pp. 285-295, Mar 1995.

[4] B.B. Hubbard, The World According to Wavelets, A K Peters Wellesley, Massachusetts, 1995.

[5] FAIRES, J.D., BURDEN, R.L. Numerical Methods. Boston, MA: PWS, 1993.

[6] HOU, H. S., ANDREWS, H.C. "*Cubic splines for image interpolation and digital filtering"*. IEEE Trans. Acoust, Speech, Signal Processing, 1978, vol.ASSP-26, no.6, pp.508-517.

[7] KEYS, R.G. *Cubic convolution interpolation for digital image processing*. IEEE Trans. Acoust, Speech, Signal Processing, 1981, vol. ASSP-29, no. 6, pp. 1153-1160.

[8] MAELAND, E. *On the comparison of interpolation Methods*. IEEE Trans. Med.Imag., 1988, vol. MI-7, pp. 213-217.

[9] PARKER, J. A., KENYON, R.V., TROXEL, D.E. *Comparison of interpolation methods for image resampling.* IEEE Trans. Med. Image., 1983, vol. MI-2, pp. 31-39.

[10] DANIELSSON, P. E., HAMMERIN, M. *High Accuracy Rotation of Images*. Department of Electrical Engineering, Linkoping University, Sweden, Tech. Rep. LiTH-ISY-I-11521990.

[11] DANIELSSON, P. E., HAMMERRIN, M. Note: *High accuracy rotation of images.* CVGIB: Graph. Models Image Processing, 1992, vol. 54, no. 4, pp. 340-344.

[12] DODGSON, N. A. *Quadratic interpolation for image resampling.* IEEE Trans. Image Processing, 1997, vol.6, pp. 1322-1326.

[13] MALLAT, S. A *Wavelet Tour of Signal Processing.Second edition,* Academic Press, 1999.

[14] CHANG, S.G., CVETKOVIC, Z., VETTERLI, M. *Resolution enhancement of images usingWavelet transforms extrema interpolation.* IEEE ICASSP, pp. 2379-2382, May 1995.

[15] CAREY, W.K., CHUANG, D.B., HEMAMI, S.S. *Regularity preserving image interpolation.*IEEE transaction.Image Process.1999, vol.8, no.9, pp.1293-1297.

[16] MALLAT, S., ZHONG, S, *Characterization of signals from multiscale edges.*IEEE transaction. Pattern Analysis and Machine Intelligence, vol.14, no.7, pp. 710-732. July 1992.

[17] HUANG, Y.L., CHANG, R.F. *MLP interpolation for digital image processing using wavelet transform.* In Proceedings of IEEE ICASSP-99, Phoenix (Arizona, USA), pp. 3217-3220.

[18] KINEBUCHI, K., MURESAN, D.D., PARKS, T.W. *Image interpolation using wavelet-based Hidden Markov Trees.*In Proceedings of IEEE Inter. Conf. Acoustics, Speech and Signal Processing, vol.3, pp.1957-1960. May 2001.

[19] WOO, D.H., EOM, I.K., KIM, Y.S. *Image interpolation based on interscale dependency in wavelet domain.* IEEE ICIP, vol.3, pp.1687-1690. Oct 2004.

[20] [20] ZHU, Y., SCHWARTZ, S.C., ORCHARD, M.T. *Wavelet domain image interpolation via statistical estimation.* In Proc. IEEE Inter. Conf. Image Proc. Vol.3,pp.840-843. Oct 2001.

[21] HATICE GUNES, MAJA PANTIC. *Automatic, Dimensional and Continuous Emotion Recognition* .I.J of Synthetic Emotions, 2010, pp 68-99.

[22] CHAVAN, TALBAR. *Multimodality Medical Image Fusion using M-Band Wavelet and Daubechies Complex Wavelet Transform for Radiation Therapy.* I.J of Rough Sets and Data Analysis, 2015.

[23] SOURAV SAMANTA, ALKOPARNA CHOUDHURY, NILANJAN DEY, VALENTINA EMILIA BALAS. *Quantum Inspired Evolutionary Algorithm for Scaling Factors Optimization during Manifold Medical Information Embedding*. ELSEVIER

[24] VIKRANT BHATEJA, ABHINAV KRISHN, HIMANSHI PATEL, AKANKSHA SAHU. *Medical Image Fusion in Wavelet and Ridgelet Domains: A Comparative Evaluation.* I.J of Rough Sets and Data Analysis, 2015, vol. 2, Issue 2, pp 78-91.

[25] SHIVASHANKAR B. NAIR, W. WILFRED GODFREY, DONG HWA KIM. *On Realizing a Multi-Agent Emotion Engine.*I.J of Synthetic Emotions, 2011.

[26] NILANJAN, SOURAV, YANG, ACHINTYA DAS, SHELI SHINA CHAUDHURI. *Optimisation of scaling factors in Electrocardiogram signal watermarking using cuckoo search.* I.J. Bio-Inspired Computation, 2013, vol. 5, pp 316-326.

[27] SHEEFA RUBY GRACE, MARY IMMACULATE SHEELA. *A Comparison on Performance Evaluation of Various Image Fusion Techniques.*I.J of Emerging Technology and Innovation Engineering, 2015, vol. 1, Issue 3, pp 129- 136.

[28] S. ZEESHAN ABBAS, K. KHURSHID. *High Speed, Noise Resistant Data Transferring System for LEO Satellite Mission.* I.J of Computer and Communication System Engineering, 2015, vol. 2, pp 238-245.

[29] NILANJAN, SAYANTAN, ACHINTYA DAS, SHELI SHINA CHAUDHURI. Analysis of P-QRS-T Components Modified Blind Watermarking Technique Within the Electrocardiogram Signal for Authentication Wireless Telecardiology Using DWT.I.J. Image, Graphics and Signal Processing, 2012, vol. 7, pp 33-46.

[30] NILANJAN, MOUMITA, ACHINTYA DAS. A Session Based Blind Watermarking Technique within the NROI of Retinal Fundus Images for Authentication Using DWT, Spread Spectrum and Harris Corner Detection. I.J. of Modern Engineering Research, 2012, vol. 2, Issue. 3, pp 749-757.

[31] TANMAY, NILANJAN, S.R. BHADRA CHAUDHRI. *A Novel Session Based Dual Steganographic Technique Using DWT and Spread Spectrum.* I.J. of Modern Engineering Research, 2012, vol. 1, Issue. 1, pp 157-161.

[32] NILANJAN, SOURAV, SAYAN, ACHINTYA DAS, SHELI SHINA CHAUDHURI, S. JASJIT SURI. Firefly Algorithm for Optimization of Scaling Factors During Embedding of Manifold Medical Information: An Application in Ophthalmology Imaging. Journal of Medical Imaging and Health Informatics, 2014, vol. 4, Issue 3, pp 384-394.

A Survey on Smartphones Systems for Emergency Management (SPSEM)

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***Abstract*—Emergency never runs with earlier intimations and indications. In the real world and practical life, detecting and perceiving such emergencies and reporting them are a genuine test and tough challenge. Smartphones Systems for Emergency Management (SPSEM) provide details of existing emergency applications and provide a new direction to overcome the traditional problem having manual intercession and reporting emergencies. In this paper, we provide a comprehensive overview of SPSEM. We elaborate how embedded sensors automate the procedure of emergency crisis detection and responding. Furthermore, we critically evaluate the operations, benefits, limitations, emergency applications and responsiveness in any emergency crisis of different approaches. We provide an easy and concise view of the underlying model adapted by each SPSEM approach. In last, we estimate the future utility and provide an insight of upcoming trends in SPSEM.**

***Keywords*—smartphone; emergency response; mobile; crises management**

I. Introduction

Emergency never comes with earlier indications in a practical life. It is a real challenge to automatically detect emergency situation and report it to the emergency management. Actually, any crisis management organization either it is private or government sector have a common goal; that is to work on the emergency plans and help those who are in crises. However, there is a big dilemma as complained by many rescue teams that they do not get “the right data in right time”. This means that sometimes emergency management teams are unable to get the right data during disaster period. Hence, delay in getting information about crisis in real time leads to delay in rescue process for saving human life. Now-a-days due to faster technology, automatic and intelligent systems, human life became comfortable, smartphone is one of such technology that is having different functionalities of user’s interests and use.

As per Indian government, department of highway and street transport report during the logbook year 2010, there were around 5 lac street accident occurred in India, which resulted in about 5.2 lac injuries and more than 1.3 lac deaths. About every 4 minutes one street accident happens there. Sadly, more than half of such accidents belong to the age group 25-65 years [1].

In an emergency, an individual who is already in crises could not be in a position to report the emergency to a response team. This is a most helpless situation where affected people need help but they lack ability to search for it. It is believed that using latest tools and technologies such as a smartphone, any disaster or emergency is perceived and automatically reported to an emergency response team. The emergency response team will then be in a position to help individuals in emergency. To accomplish this automated response, we rely on embedded sensor hardware technologies.

The role of smartphone technology in emergency management has greatly improved in tracking emergency zones, and also users can be tracked through enabled GPS. Through Internet connection, users have the ability to send and receive updates related to any disaster situation. Modern smartphones have computational platform with embedded sensors such as location detecting through maps, sensing strength of geomagnetic field. During reporting of disaster information, high power consumption is a major design challenge in the smartphones [2].

A. *Modern trends related to Emergency Management in smartphones*

A Wireless Sensor Network (WSN) is basically used in embedded systems. WSN majorly manages short range protocol whereas wireless communication uses long range protocol between two devices for communication [3]. Handheld gadgets like Personal Digital Assistants (PDAs) facilitate users with many useful options like sending or receiving information, playing games etc. When we use different smartphone applications, we use different embedded sensors such as magnetometer, accelerometer; these are directly embedded in our smartphones [4]. Advanced embedded technologies are being introduced recently and different technologies introduced in smartphones can act as a platform for emergency response because of their sensing and data exchange capabilities [4]. A person in crisis is unable to report a disaster or emergency incident. If the victim is conscious, he/she can try to escape the crises situation, otherwise, if the victim is unconscious, there should be some mechanism that can automatically invoke, detect the emergency and report it to the response teams. A timely, action and reaction in these situations is a key challenge.

B. Major objectives of SPSEM

Some of the basic objectives of SPSEM are:

- It automatically detects any disaster by using embedded sensors in the smartphone and then selects an appropriate course of action to help the needy.
- It responds in the time of critical situations by using real time system, right records are sent at right time. Also, the other stakeholders are informed automatically by SPSEM using any sensor(s) and the alerts are communicated through notifications, SMS, email etc.
- It responds in emergency situation with minimal or no human/manual intervention and interaction.

In this paper, we critically evaluate the prospects of smartphones and handheld devices which can respond efficiently and effectively in emergency situations and the emergency management systems/teams could be informed in a timely manner. Furthermore, different user's behavior and thoughts are analyzed in this research paper on the basis of smartphone emergency management applications and the intelligence used by different mobile phones to respond to emergency and crises situation is also a part of this research paper.

The rest of the paper is organized as follows: In Section II, we discuss how smartphone smartly works in any emergency situation and sends response and reports to the crisis/disaster management organization. In Section III, we discuss how social media is used as a tool for communication in crisis or disaster. Section IV describes how smartphones intelligently senses in the real time and takes timely decisions. We elaborate how smartphone works as a cloud server for processing, storing and saving different data and information in Section V. In Section V we also emphasize on working, behavior and advantages of different emergency applications. The performances of different SPSEM applications are evaluated in Section VI. The future trends about SPSEM are estimated in Section VII. The paper is concluded in Section VIII.

II. An Emergency Response and Smartphone

Based on smartphone shipment 2015 release research suggests that for 60% of all handheld gadgets are smartphones and the numbers are still growing and it is getting more popular among common people [6]. In smartphones, number of emergency applications are available that are beneficial in emergency response. Due to the innovations in GPS technology, this can be very helpful in the tracking of assets and also helpful to send information to emergency management headquarters for the analysis of destruction caused by the disaster [7].

In Bangladesh, a study was conducted about the usage of wireless technology in emergency information system. The results showed that smartphone technology may be used to spread and transmit pre disaster alerts, post disaster declarations and to send/receive data about help needed during the disaster [8]. Additionally, in emergency information administration, geographic location of those in need is very critical. Using mobile phones, destruction locations can either be calculated by using mobile positioning technology or global positioning technology. The satellite positioning mainly based on global positioning system(GPS) and network positioning basically based on the locations of Wi-Fi base stations [9] because this technology uses some nearest locations i.e., station/cell to calculate the position of smartphones thus, the accuracy of mobiles positioning is not as good as that of GPS. Hence, in natural disaster situations, global positioning system (GPS) technology is used because in such situations smartphones can rarely find any Wi-Fi signals [10].

III. Social Media: A Tool for Crises Management

The popularity of smart phones among common users is increasing gradually. Smartphone shipment data indicates that the growth will increase in coming years [11]. Nowadays, social media is being used as communication tool, platforms such as Facebook, Twitter, and Pinterest etc. enable emergency management systems to communicate instantly with the whole world or public. When it comes to the traditional media forms such as radio, television; managers of emergency management are capable to grasp a large number of audiences to provide updated information when any disaster occurs [12]. Most emergency management organizations use traditional media as well as social media for early warnings, alerts and for interaction and communication with people. In 2012 American Red Cross[13] conducted a survey and found that from out of ten four users use social networks to let family, friends know that they are safe and six percent users have downloaded and installed smartphone emergency applications that could be very beneficial in emergency[14].The limitations and strengths of social media when used as a tool for emergency management as discussed in this paper are summarized in Table 1.

TABLE I. Limitation and Strength of Social Media: A Tool for Crises Management

Strength of Social Network	Limitations of Social Network
• Internet provides reliable connection during any emergency situation. When telecommunication network fails like earthquake then we use social media as an alternative option • Through social media we grasp a broad or wide range audience; information sharing will spread quickly. • Social media gives emergency organization to communicate or deal directly with the users. • Public can receive up-to-date information with the help of social	• Over Social media false or wrong information spread quickly. During any emergency wrong information creates confusion. • All people do not use social media properly. Emergency Management must find another option to communicate with the public. • In natural disaster electric power may be affected, in this case people will not be able to charge electronic devices hence, they will not be able to approach the social network and Wi-Fi. • During emergency situation users can have non-realistic or artificial

network in any disaster situation. • Through social network people listen about disaster news instantly and quickly .People do not have to stay, wait for the traditional media.	expectations. They can expect instant response about any disaster situation. • The users need to be literate regarding usage of different forums of social media

IV. Smartphone Sensing and Mobile Enabled Decisions

A. *Smartphone/Mobile phone Sensing*

In a research study about uses of smartphones as a tool [15] users have been motivated to use sidewalks to avoid accidents. Users have been appreciated and motivated to inform about structure related problems of sidewalks by taking images with cameras embedded in their smartphones, and then these images get tagged in Google map as an input data for further urban planning in their city [16]. Schoenharl *et al* [17] developed mobile based wireless emergency response system that is able to monitor real-time geographical and social communication and activity of mobile phone users for recognizing traffic in order to support any crisis event and help destructive planners. A research was conducted in [18] in which smartphone system that supports large scale public events in destruction and emergency situations were investigated in detail.

B. *Crowd Sensing*

Crowd sensing can provide us detailed and real-time information about the situation of quickly evolving disaster to promote quick response and resource allocation effectively. Peter Haddawy [19] presents an approach for conditional assessment in crowd sensing for disaster situation. In crowd sensing Peter used mobile 4D smartphone and this mobile 4D was based on emergency alert and information system with conditional awareness information [19]. Mobile 4D is an emergency information system with bi-directional communication. When administration sends alerts, updates then Mobile 4D users receive warnings, alerts on the basis of device locations, Connections can be established through the application and it is also a crowd source system so that users at the ground level are in a position to inform about earthquakes, diseases, floods via smartphone applications, and information is sent over the internet to the administrative level. Mobile 4D is an ideal platform to provide the situation awareness [20].

In March 2014, Flight of the Malaysian Airlines was disappeared [21], through Tomnood system, digital globe posted satellite pictures and asked the users to volunteer for search at any day or time and search imagery zones of the Malaysian plane and tag any related visual like wreckage, As information/request instantly spread across the different platforms of social media, a huge number of people joined the effort. [21].

C. *3D Visualization*

Modern trends towards handheld devices such as Personal Digital Assistant (PDA), smartphones and sensor equipped devices are very important and essential for the Augmented Reality [22]. Advance trends of mobile field systems are dominated by quality control field with no redundant data. The 3D GIS databases contain 3D data structures representing both the geometry and topology of 3D shapes [23]. Visualization uses accurate tracking of mobile systems. The objective is to allow executing “key-hole Surgery” on the underground infrastructure operated by enterprises of the utility sector. In order to reduce the risk rate of human life and increase the evacuation speed and rescue can be carried out safely. Emergency responders will soon be testing devices that help in visualizing most of the current floor plans digitally on a mobile device in which an embedded accelerometer can detect the user’s organization [24].

D. *Cloud-Computing Mobile-Enabled Judgment System*

Emergency management can take many benefits from Mobile Cloud Computing (MCC) which enables storage and processing to the nearest cloud from smartphone devices [25]. Successful integration of MCC with the emergency organization, it is crucial to deal with the challenges of smartphone and cloud computing. It is very important to notice that a data backup, data redundancy is a part of the emergency management software process selection [26]. In case of a natural disaster, where there is a lot of risk of losing data centers and computers, data should be saved at multiple locations. Backup sites are geographically separate to assure that single crisis or disaster will have no impact on data centers. Natural disaster damages Internet access which makes it very difficult to approach cloud servers, data storage and applications [27].

V. Smart Phone Systems for Emergency Management Applications

In this section, we provide some existing emergency applications as an examples of SPSEM. We consider different smartphone operating systems and other hardware support provided by the specific models to support SPSEM. Table 2 presents the comparison of different attributes in SPSEM.

A. *All Android base Applications (GPS+ All versions from 4.0-5.0+5.1.1)*

1) *My Disaster Droid:*

In 2009, Fajardo and Oppus developed the Disaster Droid (MDD) application [28]. This application calculates the best route for different geographic locations. The calculated route helps the volunteer workers in disaster situation to reach up to maximum number of people in coverage area in best possible time. MDD is an implementation of Travelling Salesman Problem (TSP) and it uses genetic algorithms to generate a solution. In this application geographic locations are described as longitude and latitude. Basically, Disaster Droid shows two views first one is *Map View* and another one is *List View*. Map view utilizes the Google Maps to show the location map, while the list view displays the information regarding people in need as a list, this list also contains the corresponding location and distance. In calculating the optimum route along various geographical locations the application assumes geographic locations as cities and the rescuers as the travelling salesmen [28].

2) *Smart Rescue:*

The basic notion of Smart Rescue is to use smartphone technology to assist in delay phase in the initial crisis times [29]. Smart Rescue technology maps threats and help people in the case of emergency. If many smartphones are sensing the environment surrounding the people then those phones are used as input sources for getting threat pictures and allow and inform people to take necessary actions to avoid any hazards in the affected area [29]. The SR exploits the following objective.

- The sensor can be used to map crisis using active human-centered sensing, as a crowd sensing, thus providing the potential for environment exhaustive exploration.
- It can carry complicated tasks without draining the battery quickly and without affecting the functionality of smartphones for normal use.
- Smart Rescue supports activity recognition via sensors

3) The Wreck Watch:

When android users install this application on their smartphone devices, it effectively and efficiently integrates their mobile devices in to the sensor wireless network; this wreck watch network is also called “Smart Net” [30]. Application provides many user benefits, and it permits user to save emergency contacts on HTTP server. When collision detected, user’s emergency contacts can be informed of the emergency, accident via email, SMS. Automatic data sharing can permit responder more time to analyze the accident situation rather than updating the contacts about the situation. Another feature of this application is that a user can view the location of other wreck watch users, these features permit users to find route/path. Application user selects a marker map by tapping on specific marker. This selected option opens another menu that permits user to upload new media and this feature was only associated with the wreck watch [31].

4) Detection Smoke system:

Detector smoke system is an emergency or disaster application system that is useful in case of high flames like fire. Such types of detectors are used widely in mechanical and manufacturing factories and also used in personal and public places like, shopping malls, conferences and different public gathering areas. These detector systems in case of fire either respond and/or report emergency or disaster to central fire alarm system or alert public with some kind of audible alarm. These handheld gadgets are available and accessible in different shapes depending upon need or requirement. The older detectors were using physical ionization process whereas advanced technology utilizes the photoelectric diodes to sense the smoke in atmosphere or air. The application is used by the production or manufacturer houses to detect smoke/fire to figure out the disaster or emergency in effective and efficient manner [32].

5) First Aid Application (FA):

FA is developed to give some preliminary instructions for taking care of users in Android smartphones; basically navigation system uses Google API (maps) for searching an appropriate or suitable way or path to the nearest hospital. In the case of any emergency this function is activated on user’s smartphone to navigate victims through the shortest path to the hospital [33]. This application gives some useful instructions or precautionary measures about taking initial care of the patients before sending them to the doctors or hospitals. The application also provides the functionality of searching and finding the nearest doctor’s clinic or hospital. This application provides two types of services, first one is different sets of first aid guidance and second one is finding the accurate, appropriate and suitable hospital to go. In first service, i.e., the first aid guidance service includes the information regarding muscles, skin, or material injuries. In second service in case of emergency or disaster condition, if a patient wants to go to the nearest doctor or hospital then this application provides functionality of searching and finding, navigating or directing to the accurate, appropriate nearest clinic or hospital for patient, and the searching current location functionality starts by using smartphone’s global positioning system and then this application will ask from the patient for radius searching and at last but not least most appropriate directions to the selected clinic or hospital will be provided and it appear as an output or result.

6) Fire Ready(FR):

FSC (Fire Service Commissioner) has launched the fire ready application in 2013. FR application is the official Victoria government app for Country Fire Authority (CFA), Metropolitan Fire Bridge (MFB) and Department of environment, Land, Water, Planning (DELWP). This fire warnings and information system, notifies users of fire dangers in affected area and sends photographs of bushfire activity. Application is managed by Victoria emergency management on behalf of the fire agencies, supported by the department of Justice and Regulations [34]. User must create a zone in order to receive specific location notifications on a user’s device when incident occurs. Warnings are issued by emergency service to provide advice to the public and such information displays on the application, these warnings can include advice, watch act etc., and emergency warnings are only available on the application while they are relevant to a fire or incident [35]. On the map, warnings are placed on different locations surrounding the fire; the specific advice is also given for all affected location(s) as to how the fire may affect them.

B. All Smartphones(GPS)

1) Great Call:

Great Call application gives you authentic and easy-to-use/comfortable wireless service, this wireless system is very similar to traditional cellphones but it is only one button gadget. Great Call is the most utilized service in which any individual if is in disaster or emergency situation can communicate with representatives of the service directly upon pressing the button for help. The main feature of such service is having quick or instant response on call from trained and expert agent. In US this is mostly utilized as personal advisable device [36].

2) Quake SOS :

Quake SOS is the first app, designed for natural disaster emergency, Combination of an emergency alert system for earthquake information and SOS call for victims. The application allows to provide user’s option that if user is in an earth quake then he can notify to the contacts that either he is safe or needs help. Quake SOS contains useful information including an earthquake database, if user launches this app in his/her smartphone, the application automatically update itself every time and also provides information such as when and where earthquakes have occurred [37].

3) Saper:

Saper is basically an explosive detection application for smartphones. The word Saper is a Polish term for “mine sweeper”, at the same time acronym for “Sensor Amplified Perception for Explosive Recognition”. The application exploits the built-in magnetometer used in smartphones for compass like functionality. The application detects and works on small disturbances in the magnetic field around an explosive material. The application is connected to a cloud-based server and compares the recorded magnetic disturbance information to the information place in database for identifying the explosive [38].

4) Federal Emergency Management Agency (FEMA):

FEMA application contains awareness information about different kinds of emergency situations and disasters. The application has an interactive checklist for emergency kits, and a section plan for emergency meeting locations. FEMA basically is used for emergency awareness and preparation that what are the general ways the public can adopt pre and post-disaster. Disaster report features enable citizens to share GPS photos from the disaster area. This application uses social media to send alerts via status or email alerts to warn public of imminent threats. A study commissioned by the American Red Cross found that roughly 50% of the respondents would text for alerts, email for emergency information and help public during emergency situations [39].

5) Elerts Application:

Elerts applications are widely used in USA. The application system is centralized and used as a web and application format, Using Elert application the individual who is in emergency or disaster site can take snapshots of it, which are automatically uploaded to central website and on the other side another user of same application gets the alerts, warnings regarding such disaster, emergency along with geographic locations and images [40]. The highlights of Elerts application are provided below:

- Bi-directional communication: Once client or user gets warning or alert message on his/her cellphones, they can also reply back with other detail or elaborate information regarding disaster. Emergency teams or any other volunteers give or suggest advice or direction to get rid of emergency situation.

- Reports: Every user who has smartphone and use this application through installation on mobile phone can send direct report or response to others.

- Photos: Sharing live snapshots or images with personal security or any other user supported by alert application is a great feature.

- GPS and Mapping: Utilizing latest and advanced technology like Google Maps, through this Elert application locates the disaster place and suggest or advice others to address the issues with the details of locations.

6) Automatic Crash Notification (ACN):

Christopher Thompson presented another innovative application that is Automatic Crash Notification system. The aim or objective of this application is to save lives by reducing or decreasing time required for disaster or emergency teams to arrive to victims. ACN sensor network in automobiles is used to detect car accidents, it also communicates with a checking or monitoring station through radio cellular network. Sensor gadgets provide useful information to detect auto car destruction. Wreck watch server utilize ACN system to detect car accidents that are displayed on smartphone devices and the user is instantly allowed to access accident information through webpage [41].

C. Adhoc- Network (iPhone)

1) Help Me:

This is very important and interesting application that deals with emergency environment called, Help Me [42]. This application exhibits, introduces another good approach by using Ad-hoc network to communicate during emergency times. It would work without any help of telephone cellular network and forwards the message very smartly on the basis of hop-to-hop. It is also capable of making decision on the basis of routing algorithm to forward any message further. *Help Me* server is basically centralized to record all happening events about any disaster or emergency, once service is re-established or restored. This information is very helpful from smartphone that could also tell about the missing persons if such thing happens.

D. Web Based Collaboration tool

1) Sahana Foss:

The Sahana is an open source and free disaster system, based on web collaboration tool. It is a pluggable, web-based disaster management solution that provides optimal solutions caused by the disaster and it is also designed to help during the disaster relief phases. Current disaster system will aid in the response phase during the disaster. In this phase time quality is very important. A seconds’ delay may cost someone’s life. System determines the most optimum route for the rescuers in order to serve huge amount of people and provide maximum coverage of affected area in shortest time. [43].

E. WSN (Wireless Sensor Network)

1) Closed Circuit TV (CCTV):

CCTV basically is the utilization of cameras and wireless network to transfer a signal to its scanning box. This is not the similar to the television we have. It can be located as point to different locations or point to same location and comprises of monitoring and camera sets. These are majorly used in banks, airports, stores and clubs [44]. In manufacturing and mechanical plant, these camcorders or video cams are used to observe, scan and point to take accurate decisions while one just sitting in control room. They are also used at some other places like generation of heavy heat rooms while metal molding or other such type of areas where employees cannot sustain environments then such CCTVs are more beneficial and advantageous. A CCTV operates for a time being or continuously monitors a particular situation. Nowadays, we have advanced forms of Digital Video Recorders (DVRs) which offer flexibility and adaptability to record or monitor 24 by 7 for up to two years. DVRs frequently capturing video and record it to some disk or tape like storage. Also, CCTV has some great features like detection of faces and motion, scanning, monitoring to image processing [44].

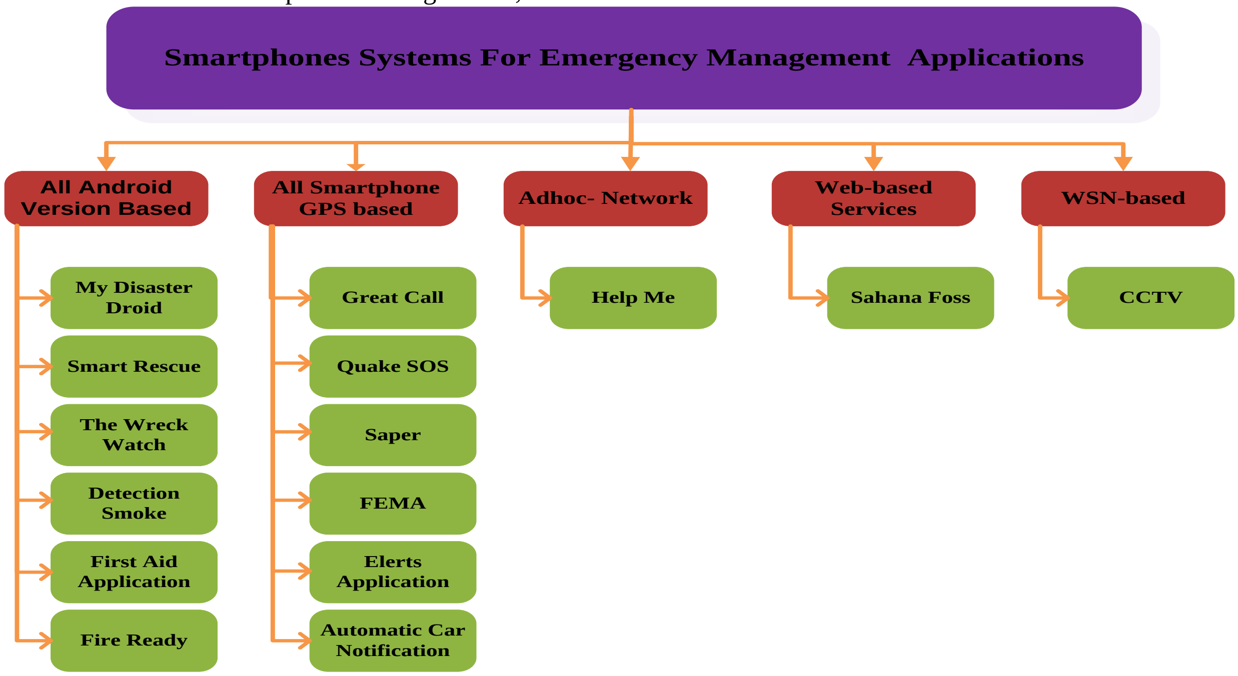

Fig. 1. Taxonomy of Smartphones Systems for Emergency Management Applications

VI. Performance Evaluation of SPSEM

We have performed detailed performance evaluation of the existing emergency applications of Smartphones Systems for Emergency Management by using different smartphone system features. We analyzed the behavior of Smartphone Systems for Emergency Management applications feature attributes like performance, availability etc. and the performance comparison of the approaches that we have discussed so far in this paper is given in Table 2. On the basis of the above discussed platforms the features we have identified and highlighted with major limitations and benefits of the Smartphone System for Emergency Management Applications are given in Table 3.

TABLE II. Comparison of the Attributes of SPSEM Applications

Categorization Of Different Platforms	Emergency System Application	Platform	Availability	Interoperability	Performance	Reliability	Portability	Usability
ALL ANDROID VERSIONS FROM 4.0-5.0+5.1.1	My Disaster Droid	Android	Yes	Yes	Best	Good	___	Yes
	Smart Rescue	Android 4.0 and above	Yes	Yes	Better	Good	Yes	Yes
	The Wreck Watch	Android	Yes	Yes	Better	Bad	No	Yes
	Detection Smoke	Detection Smoke Android	Yes	No	Good	Good	No	No
	First Aid Application	Android GPS	Yes	Yes	Good	Good	No	Yes
	Fire Ready	Fire detection Android based	Yes	Yes	Better	Bad	No	Yes
ALL SMARTPHONE GPS BASED	Great Call	All Smartphone GPS	Yes	No	Good	Bad	No	No
	Quake SOS	All Smartphone GPS+ IPhone	Yes	Yes	Good	Good	___	Yes

	Saper	Windows Phone and All smartphone based	Yes	Yes	Good	Good	Yes	Yes
	FEMA	Android 4.0 and above	Yes	Yes	Good	Yes	No	No
	Elerts Application	All Smartphone +VMS	Yes	Yes	Better	Bad	No	Yes
	ACN	All smartphone	Yes	Yes	Better	Bad	No	Yes
ADHOC-NETWORK	Help Me	Adhoc-network (iPhone)	No	No	Good	Bad	Yes	No
WEB-SERVICE BASED	Sahana Foss	Web-based collaboration tool	No	No	Good	Bad	Yes	No
WSN BASED	*CCTV*	Wireless Network	Yes	No	Good	Bad	No	No

TABLE III. PERFORMANCE COMPARISON OF SPSEM BENEFITS AND LIMITATIONS

Categorization of Platform	**Application Smartphone**	**Version Launched year**	**Benefits**	**Limitations**
ALL ANDROID VERSIONS FROM 4.0-5.0+5.1.1	My Disaster Droid	2009-10	• Using user's smartphones in any disaster location can be detected using GPS and also calculating the distance between different geo locations.	• All people can't be attended at once because of limited resources and database. • Prioritization is one the general issue.
	Smart Rescue	2012	• This application provides a great sense of security to children, girls and women's. Provide the feature of video call in which the user can explain the current condition and location of any emergency.	• Updating, redesigning the databases so we can see the related or relevant information for emergency situation • When the information mix with the sensor network of low pixels ordinary hazards pictures not executed.
	The Wreck Watch	2013	• Wreck watch provides different functionality like data recorder related to any event by recording the track and also declare emergency responses of any accident through images, video.	• It may not be conceivable to perceive all difficulties with smartphone. • Smart phones can surpass the convenience of customary in-vehicle accident ID systems.
	First Aid Application	2013	• Interactive tests to allow you to discover that you can share with your companion about lifesaving knowledge [45].	• This application is no substitute for medical treatment. • Application based on limited case or first-aid scenarios.
	Detection Smoke	2014	• This system id used to detect fire or high flames disaster through some audible and noticeable alarm.	• Definite events are not being recorded. • Neglectful or physical disable person won't able or agreed to respond, even this system attentions by strong audio signals.
	Fire Ready	2014	• In this we can watch or view rating of current fire danger in map and total fire status, GPS integration to detect location and surrounding events or happenings.	• This application sometime did not give correct information. • This application was not working on the IPhone 4 and some IPads [46]. • Sometime application is running slow when millions of users use this application.
	Great Call	2009	• This application is mostly used as a specific person device and urgent response with trained person is main key feature of such services.	• Crisis or emergency is not detected, or investigate automatically. • Emergency should be responded by a person who is in disaster, crises or emergency.
	Quake SOS	2014	• This app provides latest news and information about earthquake and also provides real-time quake disaster information for example Tsunami.	• Cannot detect adware samples. • QUAKE SOS required signal for work. • Signal requirement certainly pose a problem depending on the situation. • Smaller earthquakes won take out satellite towers and internet signals but longer one certainly could, In that case, no information could be sent or gathered [47].

ALL SMARTPHONE GPS BASED	Saper	2012	• This application is used to detect explosives and also measures around 30cm.potential risk and explosive material. • SAPER includes external wireless magnetometer and also allow for the remote detection [48].	• Saper is not intended to replace explosive detection and mine swapping technology but it provide only additional help when none are available. • Limited databases in the sense of comparison.
	FEMA	2009	• FEMA app facilitates the user with emergency helpline number, latest information related to before, after and during any crisis and emergency situation.	• Imbalance of focus between homeland security and natural disaster management [48]. • Challenge of involving public in preparedness planning.
	Elerts Application	2013	• Use Security Distance Model to measure dangerous level due to combination of requested permissions.	• Any disaster or emergency must be seen and reported by first responder, and automatically emergency not be detected.
	ACN	2014	• Smartphone can surpass the usefulness and helpfulness if vehicle has ACN framework.	• No experimental examination in genuine accident situations.
ADHOC-NETWORK	Help Me	2012	• This application is very helpful and intended to recognize missing or misplaced person through stored information in user's mobile device.	• Restrictedly depend on created ad-hoc network near or close by. • It's may not be suitable for personal emergency where a common man can stay alone like handicap adults or old-age citizen.
WEB BASED SERVICE	Sahana Foss	2006	• The response stage unites or consolidates with rescue operations for the obtainment of emergency help; in emergency situation efficiency is very important.	• The present disaster organization system does not coordinate with handheld gadgets or device that will help in the response stage in disaster.
WSN BASED	*CCTV*	2007	• Recorded features or images needs to be governed by executive to know any kind of unusual conduct.	• CCTV is utilized for observing or monitoring and not for crisis reporting.

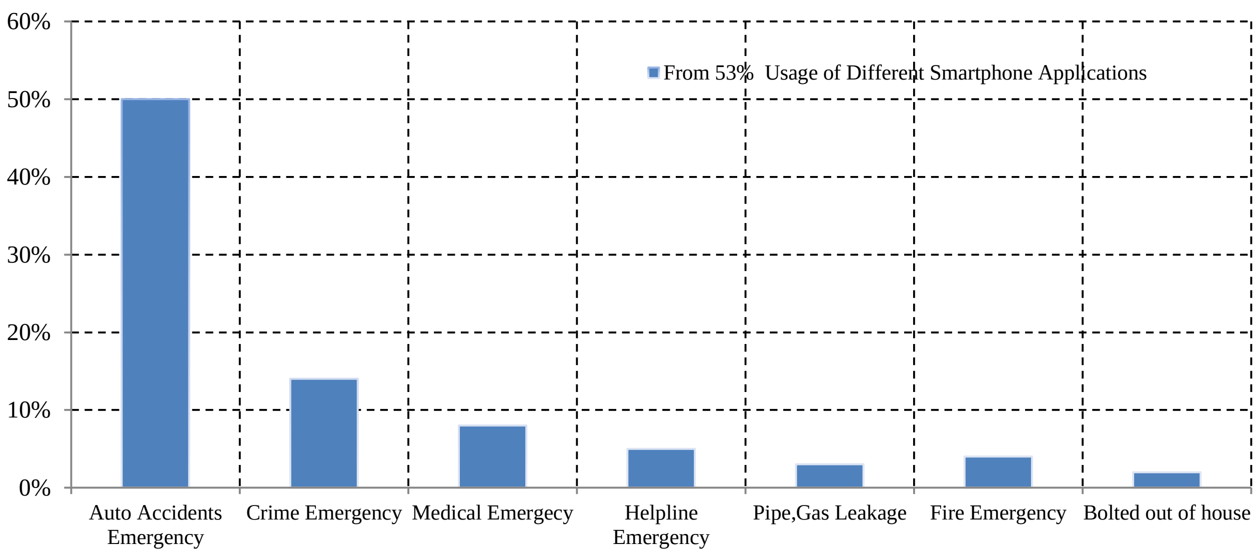

Fig. 2. Conducted by American Research and Audit center about from 53% usage of different Smartphones Emergency Applications

Through a critical examination of American research and audit center and various survey papers till 2014-2015, it is concluded that 60% of young owners use their smartphones as an instrument for emergency circumstances in which 53% energetic proprietors use emergency applications and rest of the young proprietors use contact numbers of their family, mates and most of them without using any emergency application use social media platforms through notifications irrespective of whether they are safe or not, resolve or get rid from emergency situations, conditions or circumstances by using smartphones this is in line with the findings in [49]. In a survey presented in [49], 50% users including auto accidents use their smartphones in emergency situations and 14% use their smartphones in any disaster or emergency, through handheld gadgets they notify the emergency management authorities to get help, 8% use their smart phones for medical emergency 5% use their phones for emergency helpline like 911 or HELP ME emergency app and 3% user use fire, gas application, they found it very useful in an emergency situation, also shown in Figure 2. Another assessment survey was conducted in Japan in 2013 – 2014 [50] to investigate how many people rely on smartphones emergency applications. Some interesting facts were revealed which are provided in Table 4 and Figure 3.

TABLE IV. SURVEY HELD IN JAPAN RELATED TO RELIABILITY OF SMARTPHONE APPLICATIONS

Assessment of Emergency app	%age analysis of emergency applications
Reliable	58%
Doubtful Situation	30%
Strongly Reliable	8%
Not Reliable	4%
Strongly Not-reliable	0%

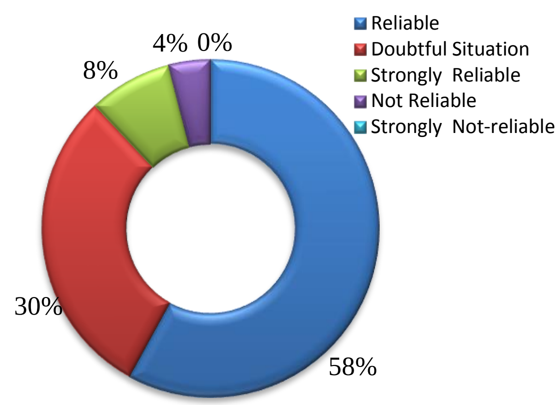

Fig. 3. Conducted in Japan 2013-2014 about the Survey Analysis of Emergency Applications

VII. FUTURE TRENDS OF SPSEM

It is expected that more devices will be connected. We compare smartphone devices and smartphone emergency application users, and those users who do not use emergency applications but upload status and notifications on social media in case of any emergency situations. According to the smartphone shipment [51] in 2012, 6.8 Billion devices were sold, in 2013, 10 Billion devices were sold. We estimate these values and forecast the future in Figure 4.

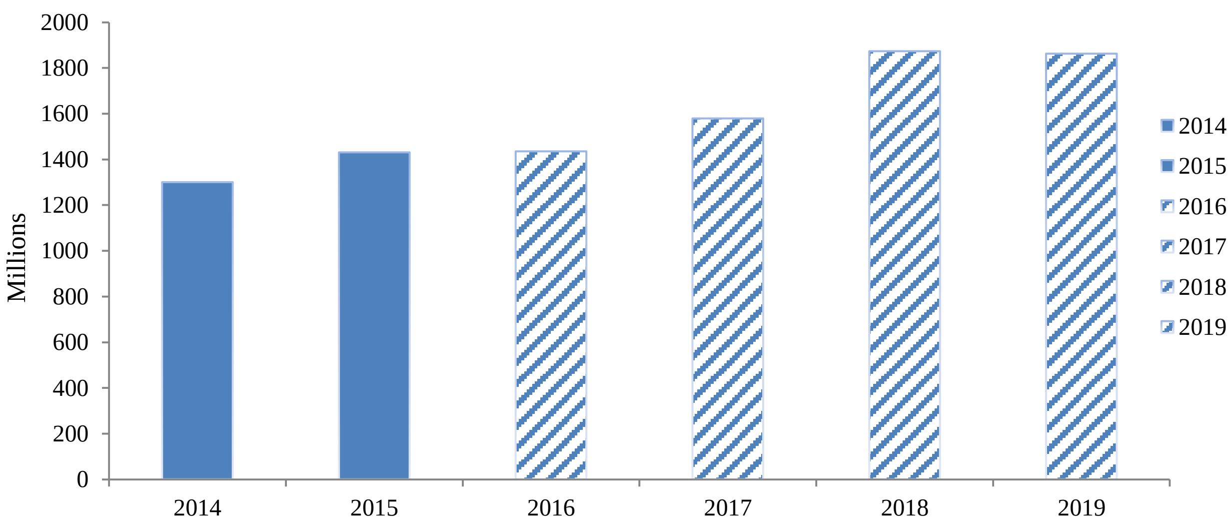

Fig. 4. According to smartphone shipment numbers of million devices were sold from 2014-215, and through smartphone shipment sold devices we further estimate that in future the number of sell device will be from 2016-2019 are shown in this graph

According to our critical analysis of different emergency applications in 2013-2014, 1300.4 million devices were sold from these devices 53% smartphones owners use their smartphones in emergency situations from 53%; 45% smartphones were used for emergency applications to resolve emergency situations. From 2014-2015, 1429.8 devices were sold; from this ratio rate 60% smartphone owners use their smartphones in emergency situations, and from 60% ; 53% users use smartphones emergency applications in emergency situation, rest of the %age inform contacts, so in 2015- 2016 according to our views or analysis if 1435.0 million devices will be sold worldwide then 67% smartphone users will use their devices in emergency situations, from 67%, 60% users will use emergency applications, From 2016 –2017 if 1579.0 million devices will be sold, from this rate 75% smartphone owners use their phones in emergency situations from 75% ; 68% uses applications of emergency management system, from 2017-2018 1873.0 million devices will be sold 84% people will use smartphones in the situations of any emergency, form 84%; 76% use smartphone emergency app. It is estimated that in 2018-2019 if 1862.3 million devices will be sold, from this 92% use smartphones devices in emergency situations, from 92% 85% will use emergency smartphones applications, this case is also shown in Figure 5.

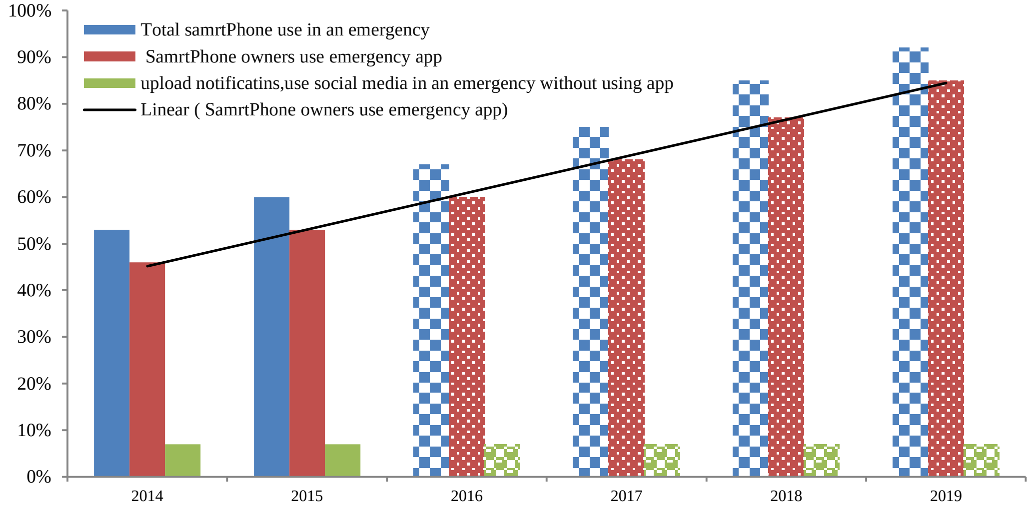

Fig. 5. From 53% usage of smartphones emergency app we further estimate or analyze that in future how many users will use smartphone emergency or disaster app from 2016-2019

Smartphone performs or offers multiple functionalities such as GPS, multimedia services and because of continuously processing of different CPU tasks the smartphones have high power demands that makes the duration of battery very minimum. Once a battery of smartphone runs out no further operation can be performed on smartphones, and smartphone emergency or crisis applications can only work properly when application installed in a mobile device executes and also sensors are enabled in a smartphone like Bluetooth etc. Another major and important thing is that in natural disaster electric supply and telecommunication infrastructure may be destroyed that could results in weak or erratic signals. Smartphone will drain or evacuate excessive battery power to search or find constantly and continuously for signals. Hence optimal management of power supply and consumption is very critical and crucial and the most important factor is that in future web services, android, iOS developers must build any mechanism or emergency applications that when smartphone battery reaches up to 20% then task manager stops all running tasks except emergency applications and sensors, this type of solution overcome the battery drainage problem in disastrous situations.

VIII. CONCLUSIONS

In this paper, we have discussed how SPSEM works effectively in an emergency or disaster through embedded sensors and installed emergency applications. We highlighted many emergency applications and discussed how these emergency applications work in smartphone devices and how emergency applications detect disasters and directly report to the central website of emergency management via satellite GPS, and social media. Our goal is to highlight the features functions, capabilities and trends in SPSEM. We highlighted various functions and technology of emergency applications, at the end it could be suggested that everybody should install different emergency applications in smartphones because in case if you are in emergency then through emergency applications you can save yourself and other people.

We believe that the upcoming smartphones will be pre-loaded with emergency and disaster management applications. The designers of the operating systems for smartphones must strive for development and embedding of emergency management applications. Furthermore, these applications must be given access to full resources in a smartphone so that emergency could be dealt in an efficient manner. In future, we aim to investigate the performance issues and overheads that are associated with emergency management applications. We also aim to survey the users' attitude towards giving maximum rights and controls to these kind of applications to respond in emergency.

REFERENCES

[1] N. D. Lane, E. Miluzzo, H. L. D. Peebles, T. Choudhury, and A. T. Campbell, "A Survey of Mobile Phone Sensing," in IEEE Commun. Mag.,vol. 48(9), pp. 140-150, 2010.

[2] M. Mun, S. Reddy, K. Shilton, N. Yau, et al, "PEIR, the personal environmental impact report, as a platform for participatory sensing systems research", in Proceedings of the 7th international conference on Mobile systems, applications, and services, pp. 55-68, 2009.

[3] E. Miluzzo, N. D. Lane, K. Fodor, R. Peterson, H. Musolesi, S. B. Eisenman, X. Zheng, and A. T. Campbell, "Sensing meets mobile social networks: the design, implementation and evaluation of the cenceme application," in Proceedings of the 6th ACM conference on Embedded network sensor systems, 2008

[4] G. Chowdhury, H. Mridul and I. Kushchu, "Prospects of Using m-Technologies for Disaster Information Management in Bangladesh and other LDCs," EURO mGOV 2005, Brighton, UK, pp. 243-253.

[5] E. M. Patil, "Emergency Reporting Using Smartphone" 2013.

[6] F. Shih, O. Seneviratne, I. Liccardi, E. Patton, P. Meier, C.Castillo, "Democratizing mobile app development for disaster management ", AIIP '13 Joint Proceedings of the Workshop on AI Problems and Approaches for Intelligent Environments and Workshop on Semantic Cities, Pages 39-42. 2013.

[7] Y. Baoquan "A Study of Smartphone Based Disaster Information Reporting System under Disaster Environment. International Journal of Smart Home" in International Journal of Smart Home, vol. 9, no. 1, pp. 45-52, 2015.

[8] S. M. Taohidul Islam, Zamri Chik,"Disaster in Bangladesh and management with advanced information system", Disaster Prevention and Management: An International Journal, 2011

[9] S. Kate. “Digital Volunteerism During Disaster: Crowdsourcing Information Processing.” Universityof Colorado, ATLAS Institute. 2011. < http://crowdresearch.org/chi2011-workshop/papers/starbird.pdf>.

[10] N. Eagle and A. Pentland, “Reality Mining: Sensing Complex Social Systems,” Personal Ubiquitous Comp., vol. 10, no. 4, 2006, pp. 255268.

[11] Thompson, Kelli et al. “Social Media Experiment: Analysis Report Executive Summary.” DHS Homeland Security Studies and Analysis Institute for DHS S&T. 28 February 2014

[12] N. Dufty. "A review of the value of social media in countrywide disaster risk reduction public awareness strategies", in the Global Assessment Report on Disaster Risk Reduction" 2015

[13] B. McElveen. American Red Cross Annual Reort 2012 (http://www.redcross.org/images/MEDIA_CustomProductCatalog/m18071523_Red-Cross-2012.AnnualReport.pdf)

[14] S. Thomas National Defense Magazine article “Social Media Changing the Way FEMA Responds to Disaster”, September 2013

[15] T. E. White,"The Application of Social Media in Disasters" 2014

[16] J. Landgren, "Shared use of information technology in emergency," in Proceedings of the Second International ISCRAM Conference pp. 35-41, 2005, Brussels, Belgium.

[17] T. Schoenharl, G. Madey, G. Szab´o, A. Barab´asi" WIPER: A Multi-Agent System for Emergency Response ", 2006

[18] A. Al-Akkad, A. Zimmermann “Involving Civilians by Smart Phones During Emergency Situations,” in ISCRAM Conference, 2011.

[19] P. Haddawy, L. Frank, "Situation Awareness in Crowd sensing for Disease Surveillance in Crisis Situations Singapore".2015.

[20] L. Frommberger and F. Schmid, "Mobile4D: Crowdsourced Disaster Alerting and Reporting", In Proceedings of the Sixth Int’l Conf. on Information and Communications Technologies and Development (ICTD '13), vol. 2. ACM.

[21] A. C. Palen, (2012). Social Media and Emergency Management.

[22] G. Schall1 and J. Sebastian, "VIDENTE- 3D visualization of underground infrastructure using handheld augmented reality" in GeoHydroinformatics: Integrating GIS and Water Engineering, 2010.

[23] D. Kalkofen, E. Mendez and D. Schmalstieg "Interactive Focus and ContextVisualization in Augmented Reality," Proc. 6th IEEE International Symposium on Mixed andAugmented Reality (ISMAR'07), pp. 191-200, 2007

[24] G. Schall, E. Mendez and D. Schmalstieg "Virtual Redlining for Civil Engineering". Proceedings of the 7th IEEE International Symposium on Mixed and Augmented Reality (ISMAR’08), 15–18 September 2008 Cambridge. IEEE.

[25] K. Mitra " A Mobile Cloud Computing for emergency management, "IEEE cloud computing published by the IEEE society, 2014

[26] D. Velev,P.Zlateva. "A Feasibility Analysis of Emergency Management with Cloud Computing Integration", International Journal of Innovation, Management and Technology, 2012

[27] R. Arden, (Aug. 26th, 2011) Surviving a natural disaster with cloud computing. Available: http://edocumentsciences.com/

[28] J. Therese B. Fajardo and M. Oppus" A Mobile Disaster Management System Using the Android Technology " ,2009

[29] O. Mokryn, D. Karmi, A. Elkayam and T. Teller “Opportunistic Smart Rescue Application and System” The 11th Annual Mediterranean Ad Hoc Networking Workshop (Med-Hoc-Net), 2012

[30] L. J. White, C.Thompson, H.Turner, B. Dougherty, and D. C.Schmidt"WreckWatch: Automatic Traffic Accident Detection and Notification with Smartphones ".

[31] S. Rauscher, G. Messner, P. Baur, J. Augenstein, K. Digges, E. Perdeck, G. Bahouth, and O. Pieske. Enhanced Automatic Collision Notification System- Improved Rescue Care Due To Injury Prediction- First Field Experience, 2009.

[32] http://www.systemsensor.com/en-us/documents/system_smoke_detectors_appguide_spag91.pdf

[33] K. Surachat, S. Kasikri W. Tiprat, and A. Wacharanimit, “First Aid Application on Mobile Device”, International Scholarly and Scientific Research & Innovation 7(5) 2013,pp-361-366.

[34] https://www.emv.vic.gov.au/our-work/victorias-warning-system/fireready-app/

[35] CFA FireReady: Victorian Bushfire Information via Smart Phone (http://www.bushwalkingblog.com.au/cfa-fireready-victorian-bushfire-information-via-smart-phone/).

[36] Official GreatCall Website. (2013, January). [Online]. Available: http://www.greatcall.com

[37] Earthquake-QuakeSOS (http://emergency20wiki.org/wiki/index.php/Smartphone_Apps)

[38] SAPER explosives detection (http://www.gizmag.com/saper-explosives-detector-app/22614/.)

[39] C. Edwards "The Federal Emergency Management Agency Floods, Failures, and Federalism" November18, 2014

[40] Official ELERTS Website. (2013, January). [Online]. Available: http://elerts.com

[41] C. Thompson, J. White, B. Dougherty, A. Albright, and D. C. Schmidt, “Using Smartphones to Detect Car Accidents and Provide Situational Awareness to Emergency Responders” in International Conference on Mobile Wireless Middleware, Operating Systems, and Applications. pp. 29-42, 2012.

[42] O. Mokryn, D. Karmi, A. Elkayam and T. Teller “Help Me: Opportunistic Smart Rescue Application and System” The 11th Annual Mediterranean Ad Hoc Networking Workshop (Med-Hoc-Net), 2012.

[43] L. Bartel, V. Walle, G. Eede, and W. Muhren, "Humanitarian Information Management and Systems, Mobile Response" Second International Workshop on Mobile Information Technology for Emergency Response pp. 29-38, 2008,

[44] L. Bigley, L. K. Zachariah, M. Everett, “CCTV camera site selection: a field experience”, 6th International VNIS. "A Ride into the Future", pp.21-27, 2015.

[45] S. Challa, "Patient Data Viewer: An Android application for healthcare", in Proc. 2011 Annual IEEE India Conference, India, 2011, pp. 1-4.

[46] http://www.smh.com.au/digital-life/digital-life-news/fireready-app-upgraded-just-weeks-after-release-20140108-30gl9.html

[47] http://emergency20wiki.org/wiki/index.php/Smartphone_Apps

[48] https://itunes.apple.com/au/app/fema/id474807486?mt=8

[49] Calloway, L. J. and P. G. W. Keen. Organizing for crisis response. Journal of Information Technology 11,1 (2009) 13-27.

[50] http://www.pewinternet.org/2015/04/01/chapter-two-usage-and-attitudes-toward-smartphones/.

[51] UNISDR. “Survey Analysis Report:the survey on persons with disability and disasters “Living with Disability and Disasters” Japan 2013.

[52] Global smartphone shipments forecast http://www.statista.com/statistics/263441/global-smartphone-shipments-forecast/

PSO-based Optimized Canny Technique for Efficient Boundary Detection in Tamil Sign Language Digital Images

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***Abstract*—For the hearing impaired, sign language is the most prevailing means of communication for their day-to-day life. It is always a challenge to develop an optimized automated system to recognize and interpret the implication of signs expressed by the hearing impaired. There are a wide range of algorithms developed for SLR, in which only few considerable approaches are carried out in Tamil Sign Language Recognition. This paper has proposed a significant contribution in segmentation process which is the most predominant component of image analysis in constructing the SLR system. Segmentation is handled using edge detection procedure for finding the borders of hand sign within the captured images, by detecting the split in the image illumination. The objective of the edge function, to find the boundary intensity, is done by a particle swarm optimization technique which chooses the optimal threshold values and implemented in the canny hysteresis thresholding method. The analysis primarily uses common edge recognition algorithms which contain Sobel, Robert, Canny and Prewitt from which the scope of the work is extended by introducing an optimization technique in Canny method. The performance of the proposed algorithm is tested with real time Tamil sign language dataset and comparison is inevitably carried out with standard segmentation metrics.**

Keywords— Tamil Sign Language; Canny Edge Detection; PSO; Thresholding; Objective Function

I. Introduction

Sign language is an inevitable tool for developing understanding skills among deaf children [16]. Exploration of SLR system is very much imperative for hearing impaired people, especially to improve their professional activities. Tamil Sign Language (TSL) is a region-based sign language considered to be a more useful means to have confined improvement in their own boundary [5]. This language is gaining factual importance since it supports an enhanced regional communication. An automated system that identifies and recognizes the TSL signs will be a fine contribution to the regional deaf community.

UGC – BSR Research Start -Up- Grant

Goyal, *et al.*, (2013) proposed a sign language recognition system based on SIFT (scale invariance Fourier transform) to recognize 26 different signs in Indian Sign Language and the feature extraction process had taken place from it to identify the signs distinctly. The outcome of the experimental study shows that the proposed method gives 95% accuracy for 45 types of input images [15]. Raut, *et al*., (2015) implemented an Otsu's algorithm for edge detection in Indian Sign Language images. The observed results indicate that the thresholding based segmentation method produces better results in terms of recognition and conversion of different signs into text [10]. Koli, *et al.*, (2015) introduced image processing technique based sign language converter for hearing impaired people and the investigated outcomes state that it gives fairly good results for recognition of different gestures [8]. Archana, *et al.*, (2014) studied vision-based hand gestures used in ISL (Indian Sign Language) interpretation system and reported that implementation of optimization techniques and algorithms could improve the efficiency of identifying various signs in the recognition system [1]. Singha and Das (2013) proposed a sign language recognition system using eigen value weighted euclidean distance for classifying different signs and the examined results illustrate that it achieves 97% classification accuracy rate for various type of 24 sign images [7].

The related works signify that a wide variety of researches are already existed in the field of Indian Sign Language recognition system. However, developing an SLR system based on evolutionary computation technique and benefaction to Tamil Sign Language recognition are an inattentive area. The main objective of this paper is to propose a major research component in the segmentation stage by using an optimal boundary detection technique with support from computational intelligence. Initially, the image is resized into 256x256 and converted into grayscale image and that image is preprocessed by optimized weighted median noise filtering technique [9]. The experiments are carried with Tamil letters like 12 Uyir and 1 Aayutha Ezhuthu and each represents the Static images of the palm side of right hand. Figure 4 depicts the generated TSL dataset. The organization of the paper is as follows: Section 2 gives the introduction over edge preserving details through thresholding concepts. Section 3 explains the implementation of conventional edge detection methods in real time TSL datasets. Section 4 explains the proposed optimized canny edge detection method using PSO. Section 5 illustrates the results and analysis based on evaluation assessments of the experimental results. Section 6 concludes the findings and analyses the scope of the research work in TSLR.

II. Edge Detection Using Thresholding

Edge detection is a process of finding the sharp contrasts in the intensities of an image, by reducing the amount of data in an image, while preserving important structural features of that image [11][14]. Edges can be classified according to their intensity profiles. Edge detection methods depend on the computation of image gradients and the type of filters used to calculate gradient estimates in the horizontal and vertical directions. If the magnitude at a pixel exceeds a threshold, edge point is identified. Therefore, the threshold value is the one which decides whether edges are present or not at an image point [6].This is determined by a single parameter known as the intensity threshold which equals the average value of image pixel intensities. The very importance of it is the understanding of the content of an image and its applications. Finding the edge pixels by thresholding is done after measuring the gradient magnitude of the image. If the threshold is low, it may detect the irrelevant features, and if it is high, it may result in segmented edges. This results in producing thick edges, even if there is a need for thinned segmentation output. The important problem that has to be addressed in this issue is the choosing of thresholds. A commonly used method for finding the appropriate thresholds can be thresholding with hysteresis. However, this problem of choosing appropriate threshold values may vary over the image [12]. This paper deals with the objective of finding the optimal threshold values by implementing nature inspired computing technique.

III. Conventional edge detection methods

In general, edge detection is performed using early brought forward algorithms such as gradient-based algorithm and template-based algorithm [14]. These algorithms are experimented and compared with the proposed algorithm to evaluate and find its quality of performance. The edge detection method is performed using three different steps, namely: Noise smoothing, Edge enhancement, and Edge localization.

A. Sobel Edge Detector

The Sobel operator is a discrete differentiation operator, and detection of edges is done by computing the image intensity function [17]. In this method, the mask seems to be on both x and y directions, but the information is combined into one single metric.

B. Roberts Edge Detector

The Roberts operator performs high spatial gradient which often corresponds to edges. Pixel values at each point in the output represent the estimated absolute magnitude of the spatial gradient of the input image at that point. Masking is done similar to Sobel operator.

$$Sobel \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

$$Roberts \begin{bmatrix} 0 & 0 & 1 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

C. Prewitt Edge Detector

Prewitt is an appropriate operator to estimate the magnitude and orientation of an edge from the kernel with the maximum response. In the experiment, the set of kernels is limited to 8 possible orientations. The result produced is very similar to Robert method as the experiment has used the same convolving kernels.

•

$$Prewitt \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

D. Canny Edge Detector

In this method, the output resultant contains thin edges, and the edge pixels are linked using edge tracking procedure. The problem of finding appropriate thresholds is handled with introducing hysteresis thresholding method [2]. It varies the threshold by tracking the edge once and finding the calculated threshold as the second resultant argument. This method is therefore better at suppressing noise and more likely to detect true weak edges [13]. Therefore, the operator finds its design to be an optimal edge detector. The discrete approximation to Gaussian function is done with $\sigma = 1.4$.

Discrete approximation $\sigma = 1.4$.

2	4	5	4	2
4	9	12	9	4
5	12	15	12	5
4	9	12	9	4
2	4	5	4	2

The Sobel operator is performed to find the approximate absolute gradient magnitude at each point with the convolution of mask G_x and G_y.

$$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \qquad G_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

The high threshold value is considered as H and the low value is named as L. In the image, if the strength of the edge is weaker than the low threshold L, the weak edge is discarded and if the strength of the edge is greater than high threshold H, the true edge is preserved. Similarly, the edge between L and H are also kept linked and finds all the edges through connected contours [4]. Figure 1 below depicts the subjective results of the conventional edge detection methods.

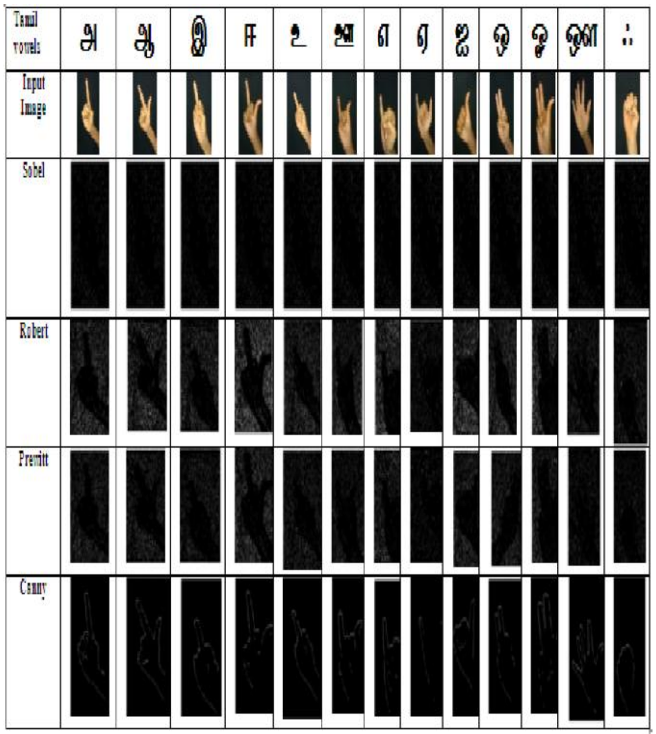


Fig. 1. Visual results of the conventional edge detection methods

IV. Proposed Optimized Canny Edge Detection Method Using PSO

Though the appropriate threshold value is chosen in canny method, the edge details that have to be preserved are more and it varies according to the image and its applications. The proposed method defines an objective to choose the optimal threshold values using PSO for implementation of the double thresholding hysteresis method which is a non-linear complex problem [3]. Figure 2 portrays the skeletal view of the canny method optimized using PSO. The particle swarm optimization finds the optimal threshold values (low L and High H) for each image and that threshold range is extracted through histogram analysis. The algorithm for the proposed method to find optimal values (L and H) is given below:

Proposed Algorithm:

Step 1: Input a Tamil sign language image I (u,v) for segmentation.

Step 2: Smoothing - Blurring of the image to remove noise by applying a Gaussian filter. The convolution of an image with a core of Gaussian filter using standard deviation of $\sigma = 1.4$ is shown in equation (1) given below.

$$B = \frac{1}{159}\begin{bmatrix} 2\ 4\ 5\ 4\ 2;\ 4\ 9\ 12\ 9\ 4;\ 5\ 12\ 15\ 12\ 5;\ 4\ 9\ 12\ 9\ 4; \\ 2\ 4\ 5\ 4\ 2; \end{bmatrix} \tag{1}$$

Step 3: Determination of gradients - Find edges by determining gradients of the input image to identify the varying intensity of the image. Gradients at each pixel are found by applying Sobel operator. It can be implemented to approximate the gradient in the x- and y-direction, respectively in the smoothed image by applying the kernels given in Equations (2) and (3):

$$G_x = [-1\ 0\ 1; -2\ 0\ 2;\ -1\ 0-1;] \tag{2}$$

$$G_y = [\ 1\ 2\ 1; 0\ 0\ 0; -1-2-1;] \tag{3}$$

where

G_x and G_y are gradient in the x and y direction respectively;

The gradient magnitudes can be determined by applying a Euclidean distance measure using the Pythagoras law as shown in equation (4).

$$|G| = \sqrt{G_x^2 + G_y^2} \tag{4}$$

Step 4: Non-maxima suppression –A gradient image has blurred edges which is transformed into sharp edges by preserving all local maxima and eliminate other pixels in the image. This process consists of the following three steps:

- Round the gradient direction θ to nearest 45°, corresponding to the use of an 8 connected

neighbourhood pixel values.

- Compare the gradient magnitude of the current pixel with the gradient magnitude of the pixel in the positive and the negative gradient direction.
- If the gradient magnitude of the current pixel is largest, then preserve the value of the edge strength. Otherwise, suppress pixel value in the gradient image.

Step 5: Double thresholding - The resultant edge pixels may still contain noise or irrelevant values. The canny algorithm uses double thresholding (high T1 and low T2) to further suppress the noise content as well as preserve the true image. Edge pixels (T) larger than high threshold (T1) are marked as strong. Edge pixels (T) smaller than low threshold (T2) are removed. Edge pixels (T) falls between T1 and T2 are considered as weak. Selection of threshold values (T1 and T2) can be viewed as a nonlinear complex problem. Here, Particle Swarm Optimization (PSO) algorithm is implemented to choose thresholds for a given sign language image.

Procedure 1 and Procedure 2 gives the steps to achieve step 5.

Step 6: Edge tracking of image by using hysteresis thresholding - The segmented image is obtained as final output image and it is used for further analysis.

Procedure 1:Steps followed to find the range of threshold values using histogram method:

Step 1: A Tamil sign language image dataset is given as input.

Step 2:The edge of sign image is predetermined as Region of Interest (ROI) in the dataset.

Step 3: Convert the input image into gray scale a image to reduce image size.

Step 4: Repeat

Identify the histogram h (z) of an image to be segmented.

Step 5: The probability of a pixel value is represented in the equation (5):

P (z) = p (z/background) P (background) + p (z/object) P (object) or

$$P(z) = P_b \frac{1}{\sqrt{2\pi\sigma_b}} e - ^{\frac{(z-\mu_b)^2}{2\sigma_b^2}} + P_o \frac{1}{\sqrt{2\pi\sigma_o}} e^{-\frac{(z-\mu_o)^2}{2\sigma_o^2}} \quad \text{or}$$

$$P(z) = P_b p_b(z) + P_o p_o(z) \tag{5}$$

where

$p_b(z)$, $p_o(z)$ - probability distributions of background and object pixels

μ_b, μ_o - means of the distributions

σ_b, σ_o - standard deviations of the distributions

P_b, P_o - a-priori probabilities of background and object pixels.

Step 6: The probability of misclassification of an object pixel as background is expressed in equation (6):

$$E_o(T) = \int_{-\infty}^{T} p_o(z)\, dz \tag{6}$$

Step 7: The mathematical equation for the probability of incorrectly classifying a background pixel as object is given in (7):

$$E_b(T) = \int_{T}^{\infty} p_b(z)\, dz \tag{7}$$

Step 8: The mathematical formula for threshold selection is obtained by minimizing the above expression as denoted in equation (8):

$$T = \frac{\mu_b+\mu_o}{2} G_y = [\,1\ 2\ 1; 0\ 0\ 0; -1 - 2 - 1;\,] \tag{8}$$

Step 9: Until the threshold values for set of images in Tamil sign language dataset are found.

Procedure2: Steps followed to find optimal threshold values (Low L and High H)

Step 1: Initialization of population and parameters - A population of threshold particles says p, of size m (0.0<=n<=1.0) are generated and initialized with random position x_p and velocity v_p.

Step 2: Fitness evaluation of particle - Each particle is evaluated with test function (rotated ellipse2) for choosing the optimal threshold values.

Step 3: Find the individual best particle - Based on the evaluation of fitness function (minima), an individual best (Cognitive) p_{best} is chosen for each iteration.

Step 4: Compare the current particle ($p_{i)}$ value with the previous value $p_{besti-1.}$

If (pi< $p_{besti-1}$)

Set $p_{best} = p_i$;

Else

Set $p_{best.} = p_{besti-1;}$

Step 5: Find the social best particle - Identify the neighbourhood (social) particle in the population and assign to index variable g.

$$V_{ij}^{(t+1)} = \omega * V_{ij} + (c_1 * r_1 * (P_{best} - x_p) + (c_2 * r_2 * (p_g - x_p) \tag{9}$$

Step 6: Velocity and position updating equation - The velocity and position of a particle is updated using the following mathematical equations (9) and (10):

$$X_{ij}^{(t+1)} = X_{ij} + V_{ij} \tag{10}$$

where

V_{ij} = velocity of j^{th} particle at i^{th} iteration

X_{ij} = Position of j^{th} particle at i^{th} iteration

$$\omega = 0.5 - \frac{random()}{2}$$

(i.e) random ( ) function generate a distributed random number which lies from 0 to 1

$c_1 = c_2 = 2.0$

r_1, r_2 = random numbers lies between 0 and 1

P_{best}= Personal best

$G_{best\,=}$ Neighbourhood (social) particle best

Step 7: Repeat the steps from 3 to 7 for maximum number of iterations.

Step 8: Continuous evolution of swarm in problem space - Particle Swarm Optimization (PSO) algorithm offer P_{best} and G_{best} candidate solution (low and high threshold values) after an evaluation of 5000 iterations.

Step 9: The resultant thresholds (high [T_1] and low [T_2]) are applied for tracking of edges in Tamil sign language image dataset by using hysteresis thresholding.

The subjective evaluation result of canny and optimized canny method using Particle Swarm Optimization is given in Figure 4.

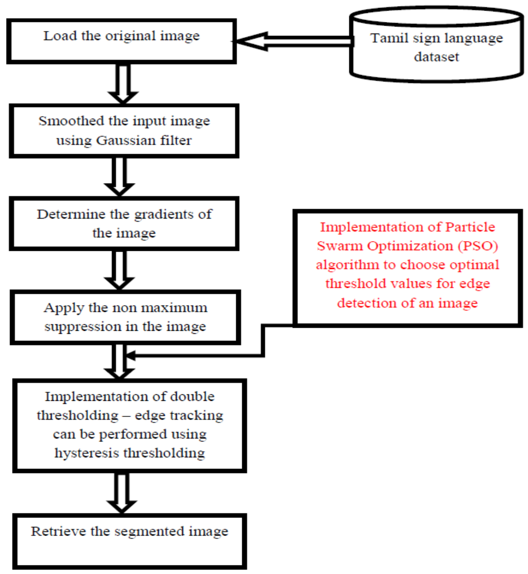


Fig. 2. Skeleton of PSO optimized canny edge detection method for regional sign language images

The canny operator uses a hysteresis thresholding method for detection of edges in the digital image. It uses double threshold values such as TH (threshold high) and TL (threshold low) where TH > TL. Pixel values greater than TH are classified as edges. The accuracy of the image segmentation process is primarily dependent on threshold value. In this work, the selection of threshold is formulized as a non-linear complex problem. PSO algorithm is implemented to choose global extremum (best solution) stochastically after the fitness evaluation of 5000 runs. The optimal solution retrieved by PSO is applied as threshold values in the canny technique to detect edges in Tamil Sign Language images. The metaheuristic approach is compatible with traditional canny method that gradually improves the probability of attaining the best results in terms of similarity measure. The empirical results shown in Tables I and II signify that the novel method of PSO based canny method produces significant results than conventional edge detectors. Moreover, it is tested with single hand signs but the experimental observation confirmed that the proposed method could perform well for different Tamil signs given by diverse sort of people. The high-quality solution obtained by PSO optimized canny technique is serviceable to hearing impaired people for convey their messages with ordinary people. The goal of this research to reinforce the performance of sign language recognition system by reduces the communication gap between normal people and deaf and dumb people.

V. Results and Analysis

The results are generated by using MATLAB and JAVA. The methodology is experimented with manually generated TSL Datasets with limitation of single handed signs and black background images.

Segmentation of the hand sign is done using edge detection method based on image brightness where it has high discontinuity issues. Though the canny algorithm supports in finding the weak edges using a double threshold method, by minimizing the error rate, identifying process of weaker edge is on the demand of the image characteristics. The performance of the canny algorithm depends on the adjustable parameters like σ the standard deviation for Gaussian filter and the two threshold values TH and T_L. Instead of tailoring the canny algorithm by adjusting the parametric values, optimization technique PSO is introduced to achieve two optimal threshold levels T_h and T_L. An example for canny and Nature Inspired Computing [NIC] based optimized canny algorithm is shown in Figure 5 which portrays the edge detected Tamil hand sign language image.

During the execution of PSO, it is terminated after 5000 fitness function evaluations. The particles which are considered to be the range of thresholds are flown and it maintains the diversity in the entire problem space. It slowly converges to give the global optimum solution. Therefore, this nature of PSO is taken to produce optimal thresholding values which are implemented in canny algorithm to improve the quality of edge detection results. The quality of the proposed algorithm can be clearly observed from the metric evaluation in which similarity index and Pearson correlation coefficients values are higher for the proposed method than other conventional methods. From the experiments conducted on TSL datasets, it is inferred that the proposed optimized canny algorithm using PSO gives better results than existing traditional algorithms.

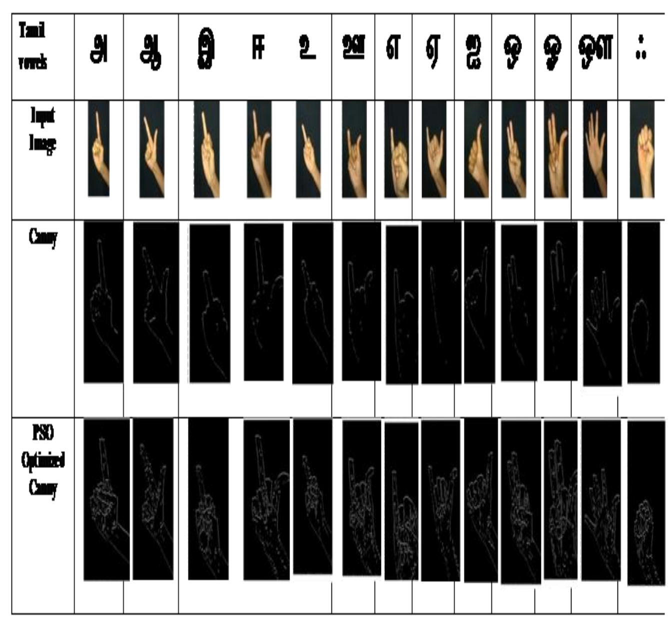


Fig. 3. Visual assessment of Canny and optimized canny algorithm

TABLE I. OBJECTIVE EVALUATION OF THE PROPOSED METHOD WITH CONVENTIONAL METHODS USING SIMILARITY INDEX METRIC

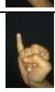
Sign language	**Image**	**Similarity Index**				
		Sobel	***Robert***	***Prewitt***	***Canny***	***PSO Optimized Canny***
அ		0.00136	0.01372	0.00046	0.01943	**0.07556**
ஆ		0.00161	0.01550	0.00041	0.01971	**0.07608**
இ		0.00120	0.01151	0.00031	0.02397	**0.08856**
ஈ		0.00318	0.02552	0.00013	0.01619	**0.06243**
உ		0.00091	0.00982	0.00041	0.01341	**0.05456**
ஊ		0.00083	0.00861	0.00032	0.01660	**0.06520**
எ		0.00191	0.01719	0.00031	0.02558	**0.09353**
ஏ		0.00012	0.00170	0.00009	0.00321	**0.01512**
ஐ		0.00213	0.01908	0.00039	0.02501	**0.09285**
ஒ		0.00134	0.01339	0.00041	0.01917	**0.07415**
ஓ		0.00154	0.01406	0.00021	0.02244	**0.08276**
ஔ		0.00022	0.00288	0.00013	0.00641	**0.02856**
ஃ		0.00025	0.00325	0.00016	0.00609	**0.02731**

TABLE II. OBJECTIVE EVALUATION OF THE PROPOSED METHOD WITH CONVENTIONAL METHODS USING PEARSON CORRELATION COEFFICIENT METRIC

Tamil 12 Uyir And 1 Ayutha Eluthukkal	**Image**	**Pearson Correlation Coefficient**				
		Sobel	***Robert***	***Prewitt***	***Canny***	***PSO Optimized Canny***
அ		-0.0501	-0.1467	-0.1095	0.0747	**0.1832**
ஆ		-0.0481	-0.1468	-0.1103	0.0719	**0.1458**
இ		-0.0646	-0.1848	-0.1378	0.0443	**0.1537**
ஈ		-0.0684	-0.0237	-0.1514	0.0455	**0.1326**
உ		-0.0440	-0.1317	-0.0979	0.0633	**0.1734**
ஊ		-0.0490	-0.1495	-0.1119	0.0407	**0.1660**
எ		-0.0603	-0.1823	-0.1364	0.0350	**0.1708**
ஏ		-0.0336	-0.1042	-0.0771	0.0380	**0.1351**
ஐ		-0.0563	-0.1652	-0.1232	0.0519	**0.1444**
ஒ		-0.0515	-0.1528	-0.1140	0.0556	**0.1828**
ஓ		-0.0631	-0.1826	-0.1367	0.0295	**0.1329**
ஔ		-0.0373	-0.1097	-0.0824	0.0548	**0.1398**
ஃ		-0.0374	-0.1123	-0.0847	0.0462	**0.1865**

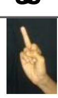
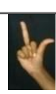
அ	ஆ	இ	ஈ	உ	ஊ	எ	ஏ	ஐ	ஒ	ஓ	ஔ	ஃ
												

Fig. 4. Manually Generated Tamil Sign Language Dataset (12 Uyir and 1 Aayutha Ezhuthu)

VI. CONCLUSION

The main objective of the paper is to develop an optimized edge detector to reduce the number of broken edges and to increase the localization accuracy of edge detection in real time digital images. The goal was successfully achieved by using PSO for optimal search of threshold values for the canny edge detector algorithm. The objective and subjective results show that the new algorithm performs better than the canny and conventional edge detection algorithms. The particle swarm optimization involves rotated ellipse2 as its objective function which is analyzed to be the best in producing the thin edge results. Experimental results validate its potential detection of weak edges while preserving the fine details of the image. The increase in the value of similarity index and Pearson Correlation Co-efficient across a wide experimental dataset reveals the same as the visual quality. In future, the work can be extended to deeply identify the finger tip detection for TSL recognition system and also to attempt multi-dimensional datasets. In the future, this study will be extended on video based sign language recognition system with dynamic signs and body gestures as well and more work has to be done in the area of feature extraction and classification process.

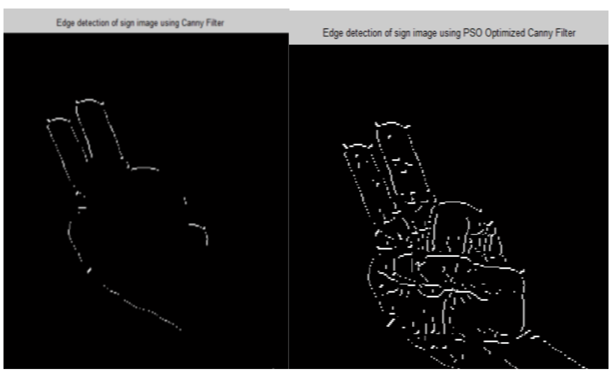


Fig. 5. Edge detected image of a hand sign image before and after optimization of canny algorithm

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REFERENCES

[1] S. ArchanaGhotkar and K. GajananKharate, "Study of vision based hand gesture recognition using indian sign language," International journal on smart sensing and intelligent systems, vol. 7, pp. 96-115, 2014.

[2] J. Canny, "A computational approach to edge detection," IEEE Transaction on Pattern Analysis and Machine Intelligence, vol. 8, pp. 679-698, 1986.

[3] G. Coath, and S. Halgamuge, "A comparison of constraint-handling methods for the application of particle swarm optimization to constrained nonlinear optimization problems," IEEE Congress on Evolutionary Computation, vol. 4, pp.2419–2425, 2003.

[4] Dongjiang Xu, and TakisKasparis, "Detection and localization of edge contours," Geo-Spatial and Temporal Image and Data Exploitation III, Proceedings of SPIE, vol. 5097, pp.79-89, 2003.

[5] P. Ghate, S. Sunder, A. Maricar, and S. Bhatnager, "An introduction to the signing system for indian languages," Part II - Additional Signs. Bombay: Ali Yavar Jung National Institute for the Hearing Handicapped, 1990.

[6] S. Jansi, andP. Subashini, "Optimized adaptive thresholding based edge detection method for mri brain images," International Journal of Computer Applications, vol. 51, pp. 1-8, 2012.

[7] JoyeetaSingha and Karen Das, "Indian sign language recognition using eigen value weighted euclidean distance based classification technique," *International Journal of Advanced Computer Science and Applications(IJACSA), vol.4 ,pp. 188-195.*

[8] P.B.Koli, Chaudhari Ashwini, MalkarSonam, PawaleKavitaandTaydeAmrapali, "Image processing based language converter for deaf and dumb people," *IOSR Journal of Electronics and Communication Engineering (IOSR-JECE), vol. 5, pp. 25-30. 2015.*

[9] M. Krishnaveni, P. Subashini, and T.T. Dhivyaprabha, "Efficient removal of impulse noise in tamil sign language digital images using pso based weighted median filter," International Journal of Applied Engineering Research (IJAER), vol. 10, pp. 40474-40480, 2015.

[10] D. ManishaRaut, PallaviDhok, KetanMachhale, and JaspreetManjeetHora, "A system for recognition of indian sign language for deaf people using otsu's algorithm," International Research Journal of Engineering and Technology (IRJET), vol. 2, pp. 228-232, 2015.

[11] Nassir Salman,"Image segmentation based on watershed and edge detection techniques," The International Arab Journal of Information Technology, vol. 3, pp. 104-110, 2006.

[12] H. Pan, L. Wang, and B. Liu, "Particle swarm optimization for function optimization in noisy environment," Journal of Applied Mathematics and Computation, vol. 181, pp. 908–919, 2006.

[13] L. Philip Worthington, "Enhanced canny edge detection usingcurvature consistency," IEEE Transactions on Graphics and Image Processing, vol. 55, pp. 95-105, 2002.

[14] Raman Maini, and Himanshu Aggarwal, "Study and comparison of various image edge detection techniques," International Journal of Image Processing (IJIP), vol. 3, pp. 1-10, 2010.

[15] SakshiGoyal, Ishita Sharma, and Shanu Sharma, "Sign language recognition system for deaf and dumb people," International Journal of Engineering Research & Technology (IJERT), vol. 2, pp. 382-387, 2013.

[16] TirthankarDasgupta, Sambit Shukla Sandeep Kumar, SynnyDiwakar, and AnupamBasu, "A multilingual multimedia indian sign language dictionary tool," The 6th Workshop on Asian Language Resources, pp. 57-64, 2008.

[17] Wenshuo Gao, Lei Yang, Xiaoguang Zhang, and HuizhongLiu,"An improved sobel edge detection," vol. 10, pp. 67-71, 2010.

Enhancement of KaPoW Plugin to Defend Against DDoS Attacks

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***Abstract*—DDoS attack is one of the hardest attacks to detect and mitigate in the computer world. This paper introduces two quantitative models, which use the client puzzling to detect and thwart application DDoS attacks. We simulated the models to use the probabilistic metrics to penalize the malicious users and prevent them from launching a DDoS attack while offering a stable environment to the normal users and decreasing the number of false positives and false negatives.**

Keywords—Application Security; Client Puzzling; DDoS; Metrics; PHP; Puzzle

I. Introduction

Distributed Denial of Service (DDoS) attacks is one of the most rapidly increasing threats to the Internet eco-system. It has been increasing almost exponentially leaving the servers always wanting more bandwidth. Nowadays, DDoS attacks may be more than 100Gbps which is 10 times the size of most internet backbone pipes.

DDoS is DoS taken to a whole new level using diversification, obfuscation and distribution of the attack origin. DDoS is launched using many computers on one or more victims to prevent the legitimate users from accessing the network resources [1,2].

Over the past years, many defenses techniques were introduced to defend against DDoS attacks: Whitelists [3], Blacklists [4], VIP lists [5], Captcha [6]. But they all had some disadvantages e.g. false positives and false negatives.

In this paper, we applied the Client Puzzling approach to defend against the DDoS attack. It's a Proof of Work (PoW) [7] technique where the client proves that it has done some work, by solving medium to hard puzzles, in return to get the needed resources from the server and to prove its legitimacy [8,9].

II. Related Work

A. Client Puzzling

Client Puzzling is a protection technique, characterized by its capability to be integrated into any web application with minimal alterations to the infrastructure and software components. Dwork and Naor were the first people to suggest the use of client puzzles to limit the junk email [10,11]. But unfortunately, client puzzling has its shortcomings for adversaries with parallelization capabilities, or legitimate flash-crowds [8].

B. Puzzles Difficulty Calculations

The puzzle difficulty can be determined based on the server load, the client behavior or just fixed difficulty [8]. In cases where the difficulty is based on the server load, the puzzle difficulty increases as the server runs out of resources regardless of their maliciousness. That's why it is the worst for the legitimate clients. It's better to determine the puzzle difficulty based on the client's behavior to penalize the attackers by giving them harder puzzles than the normal clients. Yet, this will require the server to track the client's behavior by using client identifying information, such as the client's IP address or the assigned nonce tokens. In the fixed difficulty all the clients are not required to solve a puzzle. However, when the server resources are occupied above a certain threshold, all the clients receive a puzzle with a pre-defined fixed difficulty.

C. KaPoW

KaPoW is a PoW based technique, implemented as libraries and can be used by the web applications to enhance the performance of anti-spam techniques such as: Captcha and spam filters [13].

There are two implementations for using KaPoW to protect the web content:

- KaPoW Apache module known as Mod_KaPoW. It is an Apache2 module which is almost transparent for the application. It embeds the puzzling and the solver mechanism in a way that changes the application on-the-fly [14,15].
- KaPoW plugin which is a PHP library that allows the puzzles to be embedded in the HTML tags, solved by JavaScript and verified by a server-side component [16]. Two existing applications for KaPoW plugin are KaPoW webmail filter and KaPoW anti-spam filter.

KaPoW calculates the puzzle difficulty based on multiple metrics. The total score is calculated by summing all the metrics' scores:

$$\text{Score} = S1 + S2 + ...Sn \qquad (1)$$

where n is the number of used metrics. The user will receive a puzzle with difficulty (Dc) based on his score. The difficulty is calculated using:

$$Dc = m \times (\text{score})^n \qquad (2)$$

where *m* is an arbitrary empirical constant [16].

D. KaPoW Modules

As any client puzzling system, KaPoW plugin consists of three components: the puzzle issuer and verifier at the server-side and the puzzle solver at the client-side. The issuer generates the puzzle and delivers it to the client. After the client receives the puzzle, the solver generates random solutions to these puzzles until a correct solution is found and sent to the server. Finally, the verifier accepts or rejects the solutions, sent to the server, based on their correctness, legitimacy and freshness [16]. Fig. 1 describes the system architecture of KaPoW Guestbook. The same architecture is followed in the proposed models.

E. KaPoW Guestbook

KaPoW Guestbook [13] is an open source project under GPLv2 License and implemented in PHP. It solves the modified time-lock puzzles using a JavaScript solver which is called via AJAX which allows solving the puzzle in the background.

KaPoW Guestbook can be integrated in any application because of its modularity; which makes it easy to add after the application is already developed; there is no need to make changes in the core modules of the applications.

KaPoW Guestbook's browser side displays the comment form to the user asking him to enter his name, e-mail, comment and IP address. Then the user submits the form, and a new puzzle is requested.

When the server receives a request for a new puzzle, it invokes SpamAssassin to detect if the contents contain any spam data. Then the server checks the blacklists and returns the threat score. The difficulty (Dc) is calculated based on (2). After calculating Dc, the server nonce and the difficulty are returned as a response to the JavaScript. The client tries to solve a hash function using the information sent by the server. Finally, when the answer is found, the client submits it to the server. If the server verifies the answer is correct, it'll accept the new message and will display all the messages, otherwise it will reject the submission and will only display the old messages.

III. Proposed Model "DDOS_KAPOW"

Client Puzzling has proven its capability and efficiency at defending DoS and spam attacks, that's why we decided to apply it to defend against DDoS attacks.

After examining the KaPoW_Guestbook open source code, some discrepancies were found that prevented the code from running. So, we solved the problem with the SpamAssassin and to save bandwidth, we applied caching on the message content. Also, to make the code run, we replaced the blacklists used by the authors, by "DShield Blacklist" because they didn't exist anymore.

KaPoW Guestbook's original implementation was done using two metrics Spam filter and IP Blacklist to detect the presence of Forum Spam attacks. "DDoS_KaPoW" is an implementation of KaPoW Guestbook, it uses the same architecture but with some enhancements made on the individual modules and the used metrics to adjust them to the setup environment and to defend DDoS attacks instead of spam attacks.

We modified the user interface and the core engine using a Resource Intensive Operation "RIO" (some calculations in the background which makes the post message action does some processing) to simulate the CPU intensive operation. We substituted the spam filter metric by the processor load since it is known as one of the most important factors indicating the presence of a DDoS attack. Since DDoS_KaPoW focuses on the freshness of the client puzzles, we made the nonce Nc random for each request and it is submitted with the answer for verification instead of being constant like in KaPoW Guestbook. The constant Nc in KaPoW Guestbook will allow the attackers to generate multiple requests using the same answer. We added the capability to enable and disable the Client Puzzling which will help us in the evaluation of the models. We also added an internet connectivity check because of the regularly updated services which require an internet connection e.g. blacklist.

Finally, DDoS_KaPoW checks if the user is an attacker by checking the processor load and the IP blacklist. If the processor load is higher than a predefined threshold, the score is increased by 8. If the user's IP address exists in blacklist, the score will increase by 5. At the end, the puzzle difficulty is calculated using (2).

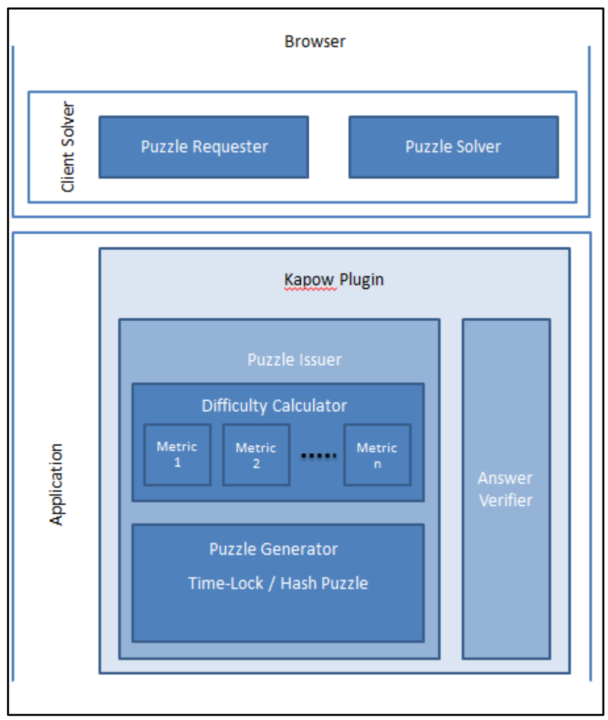

Fig. 1. System Architecture of KaPow Guestbook

IV. Proposed Model "Z-Pow"

This proposed model describes enhancement options to mitigate application DDoS attacks based on the previous work's deficiencies taking into consideration the various dependent and independent variables, the nature of problem at hand and the technological environment limitations. It is called

Zombie Proof of Work or "Z-PoW". Due to the vulnerabilities found in the old techniques, Z-PoW combines the effectiveness of anti-spam defense and anti-DoS defense to defend against DDoS.

Z-PoW is a mutation of the client puzzling implementation in Mod-KaPoW and KaPoW plugin. It combines the concept of the client's maliciousness score and the equation needed to calculate a combined score from these metrics taken from the DoS protection in Mod-KaPoW, in a framework similar to that used in KaPoW plugin. However, Z-PoW proposes multiple new metrics to detect DDoS.

A. Architecture

Fig. 2 displays the flowchart of Z-PoW's browser-side. At the beginning, the browser reads the puzzle from the server. After that, the browser generates a possible puzzle solution. If this solution is incorrect, it will try another one. But if the solution is correct, it will read the operation argument and will send it to the server along with the difficulty and the answer. If the operation is not complete, an error message, received from the server, will be displayed.

0 displays the flowchart of Z-PoW's server side. The server reads the operation which can have three values: "null", "preview" and "submit". If it's "null", it'll display all the old operations. On the other hand if it's "preview", it will first check whether the client puzzling is switched on or off. When the client puzzling is off, it will only make the difficulty equal to zero. But when the client puzzling is on, the score is initialized by zero. Then the server does several checks to calculate the score based on different metrics. These metrics check if the request is coming from The Onion Router (ToR), is a referrer, is blacklisted, is not permitted in the country, is a proxy, is a user agent or is the processor high, then the score will increase if one or more of the metrics is true by 1, 6, 5, 4, 1, 1 and 8 respectively. When the calculated score is less than the threshold, the difficulty will be equal to zero. But when the calculated score is higher than the threshold, the server will return a puzzle with a calculated difficulty. Finally, when the operation is "submit" and the client puzzling is on, the server will read the IP address, the answer, the difficulty and the operation. The server will also generate a puzzle based on the IP address and the given difficulty. After that, it validates the answer. In case the answer was wrong, an error message is displayed. However when the answer is correct, the operation is executed and the argument is saved.

B. Attack Identification Metrics

Based on [4,13,16,19], many factors were identified to help indicate the presence of a DDoS attack or that the user is potentially an attacker. The following factors are used as the puzzle metrics based on their disadvantages and their difficulty of implementation.

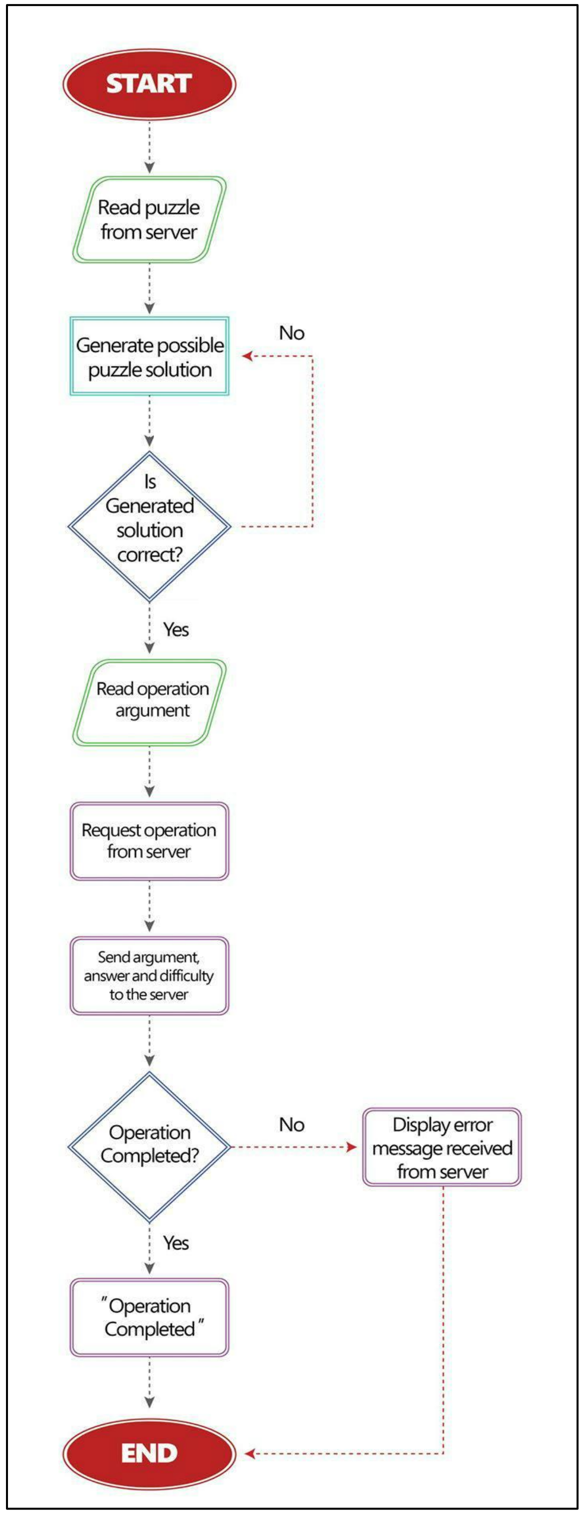

Fig. 2. Z-PoW's Browser Side

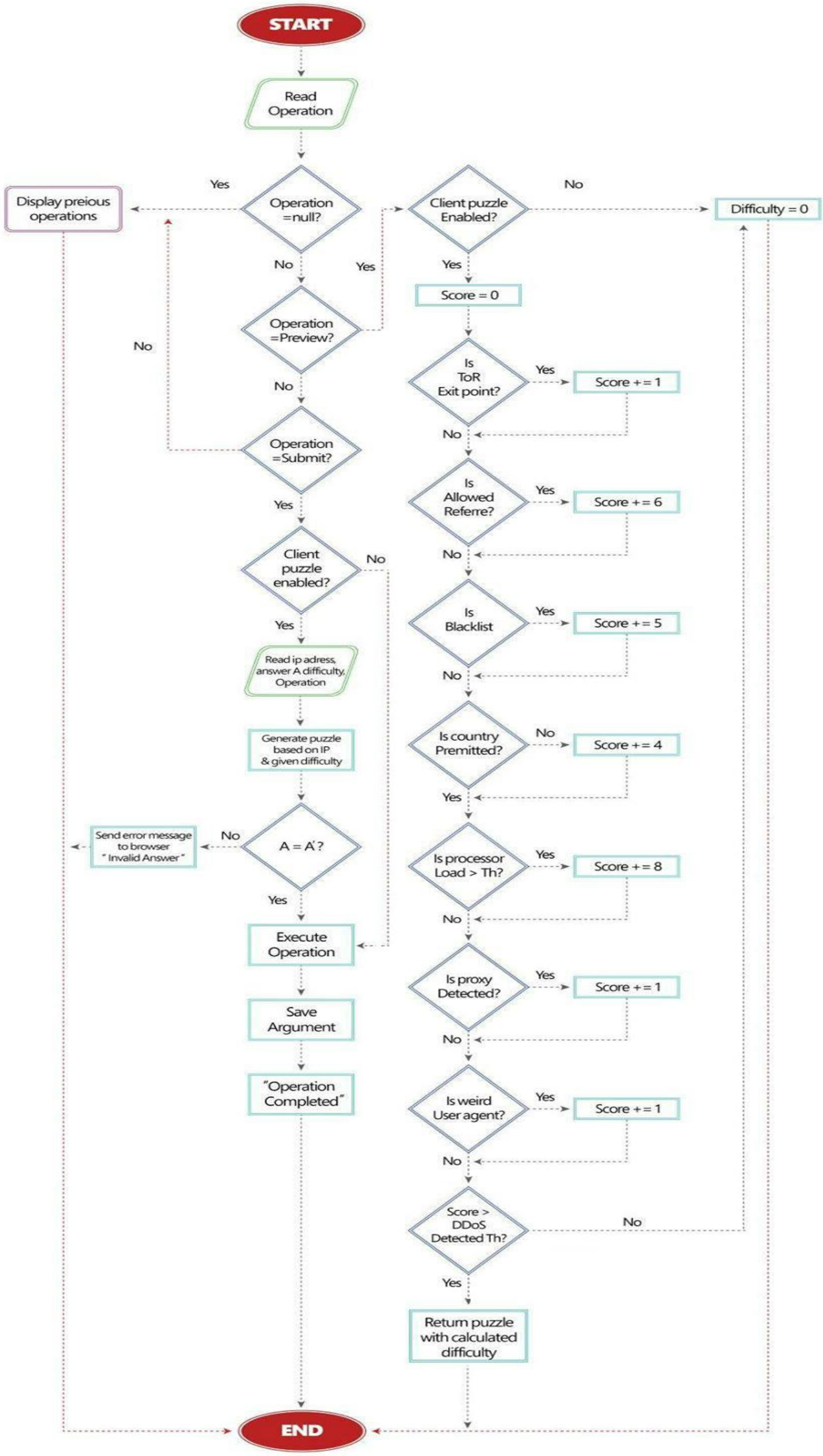

Fig. 3. Z-PoW's Server Side

TABLE I. METRICS SCORE CALCULATION

Metric	Blacklist	Processor	Geographical Location	Referring URL	ToR Network	Proxy Server	Weird User Agent
Overhead (Network Processing)	High	Low	High	Low	High	Low	Low
False Positives	Medium	High	High	Low	High	High	High
False Negatives	High	Low	High	High	High	High	High
Can be bypassed	No	No	Yes	Yes	No	Yes	Yes
Probability of metric occurrence given there is an attack launched	Med	High	Med	Med	Med	Med	Med
Probability of having an attack given that the metric is high	High	Very High	High	Medium	Low	Low	Medium
Impact on normal user	High	High	Low	Low	High	High	Low

Two of them are already used in DDoS_KaPoW: the existence of client's IP address in a blacklist and the increase in the server processing load. Other factors are used like using the client's geographic location to identify the clients who wouldn't normally access the server. Also, the absence of the referring URL indicates that this client is most likely a bot or a malicious user. If the request is originated from a bot then the user agent will probably have a signature which is known as one of the bad user agents. Although, in real life, the normal clients can use anonymizing networks, such as ToR and Proxy for privacy, but still the malicious users can exploit them to launch an attack.

C. Maliciousness Score Calculation

After selecting the metrics used to identify the presence of a DDoS attack, we established some factors to measure the effectiveness of each metric and assign its score. These factors are the processing overhead, false positives, false negatives, how difficult the metric can be bypassed, the probability of its occurrence, the accuracy of the metric and finally the negative impact on the normal clients as shown in . We gave each factor a score based on its variability. At the end, the score and the difficulty are calculated based on equations (1) and (2).

D. New Modules

In order to apply the new metrics, we integrated the proposed models with third party services and libraries like Windows Management Instrumentation (WMI) objects to calculate the processor load. We also integrated Z-PoW with DB-IP database to determine the client's geographic location, a referrer anomaly detector, ToR and Proxy detection libraries and finally a user agent anomaly detector.

E. Attack Simulation

During the implementation of the DDoS attack simulation, there was a problem with the browser automation because of its limitation of maximum number of simultaneous requests to the same domain. We tried many solutions like different browser profiles, different browsers instances using Selenium, different webdrivers using Python-Selenium Library, JavaScript to Python engine and Virtual machine with BeEF. But still all these solutions were neither satisfying nor feasible to solve the problem. At the end, we used a command line standalone JavaScript engine "PhantomJS" to conduct the attack simulation

We simulated the malicious user agents and proxy headers by injecting custom user agent and proxy randomly from the code. We added a module to select randomly from a list of the source IP addresses and feed it to both the simulated source IP header and the proxy header to simulate the clients behind a proxy. Also, we handled the case of unsolved puzzle, such that the operation will be discarded and the user's browser will have to request a new puzzle to solve (Retrying Request).

V. EXPERIMENT SETUP

A. Network Setup

To build the network, we used 5 machines: one machine acting as a server and 4 machines serving as clients (good and malicious). The server machine has 4GB RAM with Windows 8.1. The clients' machines: one has 1GB RAM with Windows 7 Ultimate; one has 3GB RAM with Windows 7 Professional; one has 2GB RAM and Windows 7 Starter and one with 4GB RAM and Windows 7 Ultimate. We built the network using an 8-port 100 Mbps desktop switch and straight through Ethernet cables.

B. Software Setup

On the server machine, we used XAMPP v3.2.1. Also, PHP v5.4.19 and Apache v2.4.4 were used. We used NetBeans IDE and xDebug to run all the models. Finally, to execute the simulation consoles remotely, we mounted the network drives. The server is designed to give priority to malicious users over normal ones. So as suggested in [14], we applied the limitation of accepting 4 clients simultaneously in DDoS_KaPoW and Z-PoW using Multi-Processing Modules "MPM" parameters. Also, we changed "PHP.ini" parameter to control the maximum execution time and adjust the default value from 30 to 80 seconds.

C. Simulation Assumptions

When the good and the malicious requests are sent; we send the good requests from one client machine using 2 consoles; except during experiment 1 and 2, we only use 1 console since the number of the good requests is very small. On the other hand, we send the malicious requests from the other clients' machines through 5 consoles. But when we only send good requests, they are distributed among all the clients' machines using 5 consoles on each. No requests are sent from the machine acting as the server. We used 900 seconds (15 minutes) as a threshold after which any request will be ignored because it's not feasible for an attacker to wait all that long for a single request; it's easier for him to launch a new attack.

VI. RESULTS AND ANALYSIS

We have made various tests to measure the efficiency of the proposed models, and we have altered many variables to evaluate them in different environments and capture their performance. These tests aim to reveal the benefits and overheads of using client puzzling to defend against DDoS attacks. We conducted 10 experiments; each experiment consists of 6 tests. TABLE II and TABLE III display the different experiments and tests applied to test the setup and the behavior of the models under different environments and conditions.

While running the experiments, we noticed that a considerable amount of time was spent to process the good requests when the client puzzling is on. This wasn't desirable and affected the aim of the models. This amount of time was caused by the lookup for the ToR network. We removed this metric which saved a lot of time such that the average time taken by the requests during the presence of the ToR metric is triple the average response time during its absence.

A. Client Puzzling on vs off

We can conclude from Fig. 4 and Fig. 5 that the average response time of the good requests during tests ON/V/G and ON/F/G is higher than test OFF/G. This makes perfect sense because this gap represents the time taken to check the user maliciousness; it's the cost of security. We can also observe that the average response time of the good clients during test ON/V/G is almost the same as test ON/F/G with very few tweaks.

From Fig. 6 and Fig. 7, we can conclude that both models have almost the same behavior with very few differences, when only good requests are sent, whether the puzzle difficulty calculation was varied or fixed. Furthermore, the average response time in both models is directly proportional to the total number of requests. In Test OFF/G, the puzzle difficulty remains zero, throughout all the experiments in both models, as the client puzzling is switched off. During test ON/F/G, the difficulty also appears to be zero since the good clients' requests never exceeded the predefined threshold. Based on TABLE IV, in Test ON/V/G, the client will receive a puzzle difficulty with either zero or 131072 in Z-PoW and 32 in DDoS_KaPoW. These numbers '131072' and '32' refer to the difficulty calculated based on equation (2) when there is a high load processing on the server and the score is substituted by the processor load score which is 8 as mentioned in section IV. There are some exceptions in Test ON/V/G where the difficulty is zero like in Z-PoW' experiments 1 & 2 and DDoS_KaPoW experiments 1, 2 ,3 & 4. These exceptions are due to the small number of the sent requests such that it didn't affect the server processor.

TABLE II. DIFFERENT TESTS USED

Test	Client Puzzling on/off	Client Puzzling varied / fixed	Good or/and malicious Clients
OFF/G	OFF	-	Only Good
ON/V/G	ON	Varied	Only Good
OFF/GM	OFF	-	Good & Malicious
ON/V/GM	ON	Varied	Good & Malicious
ON/F/G	ON	Fixed	Only Good
ON/F/GM	ON	Fixed	Good & Malicious

Either in Z-PoW or DDoS_KaPoW, all the requests coming from the good clients, with or without the client puzzling, received a response. There weren't any requests dropped even when the total number of requests was increased four times.

B. Varied Puzzle Difficulty Calculation

In reference with Fig. 8 and Fig. 9, in both models during Test OFF/GM, the average response time of the malicious and the good requests are close to each other.

On the other hand, in Test ON/V/GM, the average response time of the malicious requests is way greater than the average response time of the good ones. Sometimes, the average response time of the malicious requests is 25 times the average response time of the good ones. This proves that the client puzzling enhanced the good users' experience and punished the malicious clients by giving them complex puzzles and hence delaying the response of their requests.

TABLE III. NUMBER OF CLIENTS DURING DIFFERENT EXPERIMENTS

Exp.#	Number of requests (good clients only)	Number of requests (both good and malicious clients)	
	Good	*Good*	*Bad*
1&2	280	25	255
3&4	560	50	510
5&6	1100	100	1005
7&8	2200	200	2010
9&10	4400	400	4020

Fig. 10 shows that during Test ON/V/GM, Z-PoW's performance is better than DDoS_KaPoW because the average response time of the malicious clients is very high in Z-PoW while it's slightly higher than the average response time of the good ones in DDoS_KaPoW.

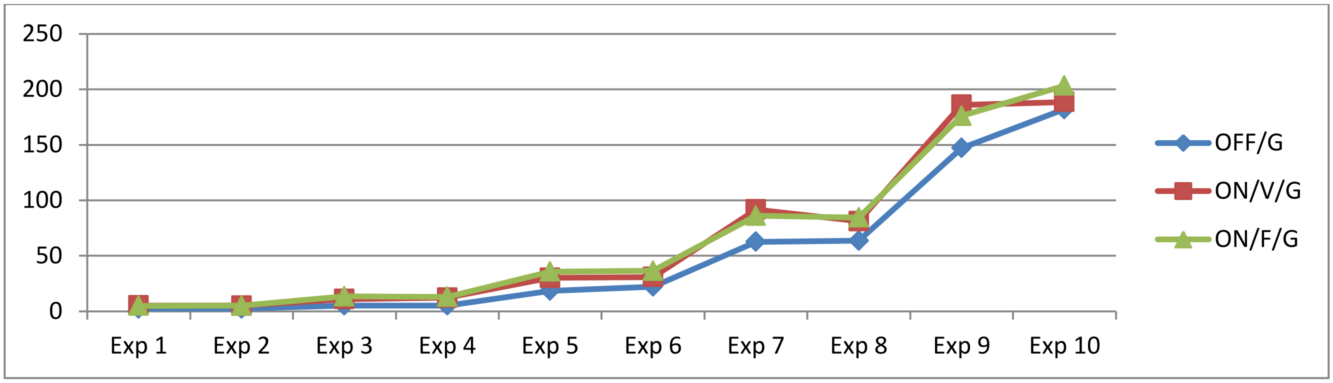

Fig. 4. Z-PoW's Average Response Time during Tests OFF/G, ON/V/G and ON/F/G

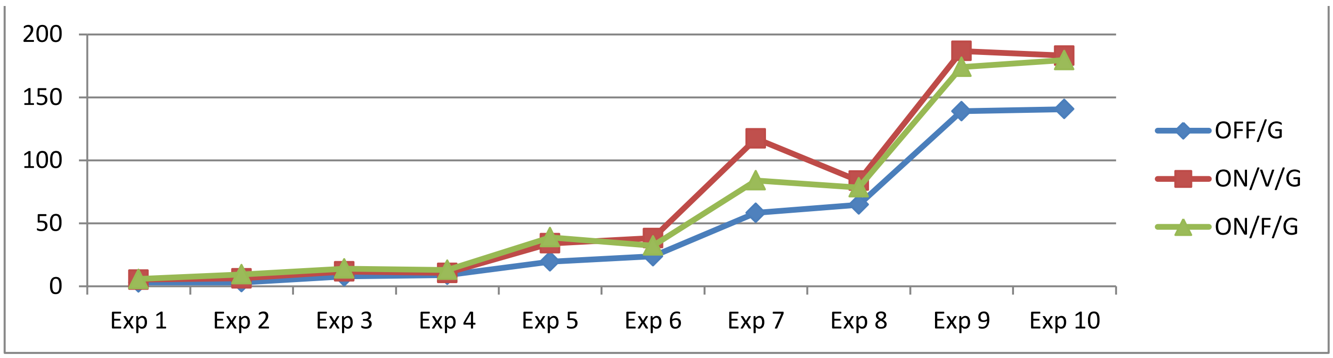

Fig. 5. DDoS_KaPoW's Average Response Time during Tests OFF/G, ON/V/G and ON/F/G

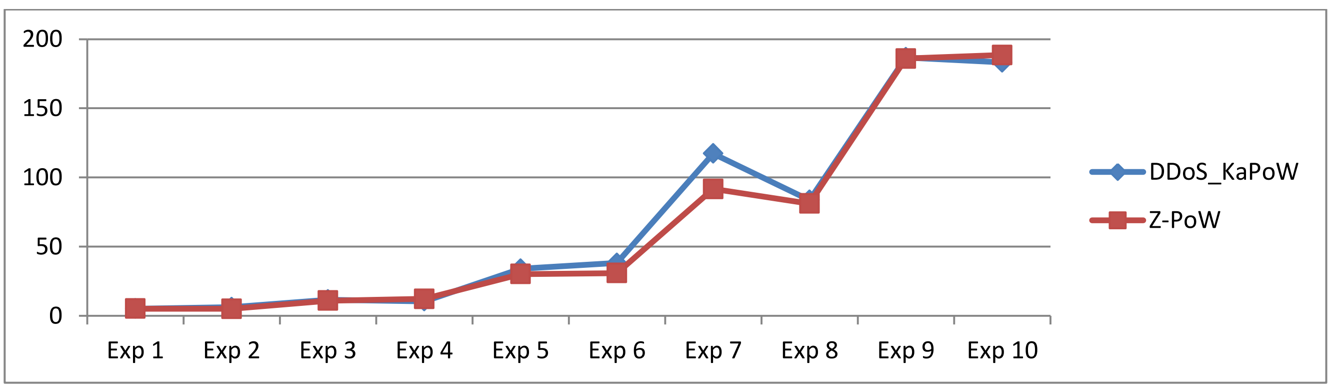

Fig. 6. Average Response Time of Both Models during Test ON/V/G

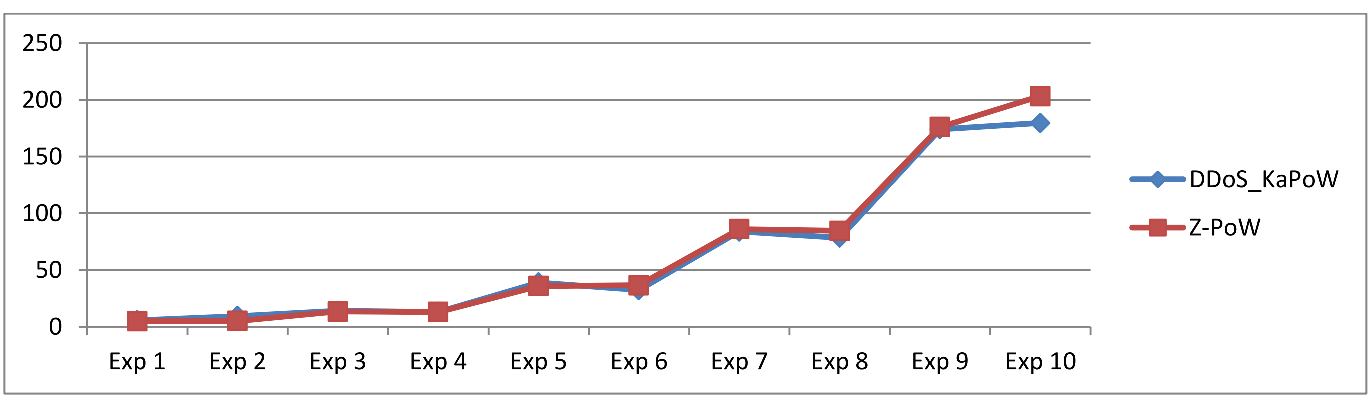

Fig. 7. Average Response Time of Both Models during Test ON/F/G

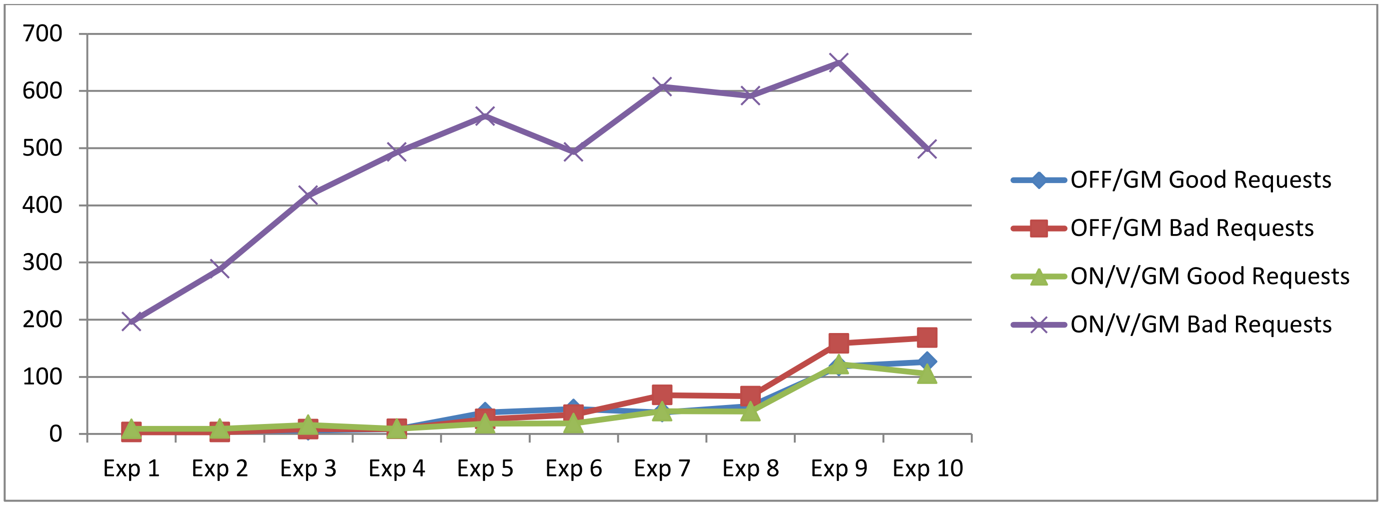

Fig. 8. Z-PoW's Average Response Time during Tests OFF/GM and ON/V/GM

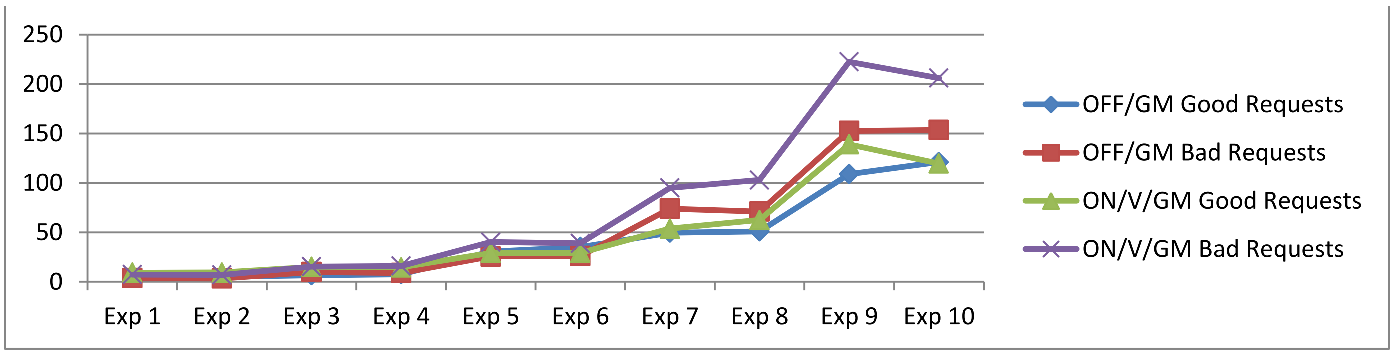

Fig. 9. DDoS_KaPoW's Average Respone Time during Tests OFF/GM and ON/V/GM

TABLE IV. THE MINIMUM AND MAXIMUM DIFFICULTY OF BOTH MODELS DURING TEST ON/V/G

ON/V/G Puzzle Dc	Z-PoW Dc		DDoS_KaPoW Dc	
	Min	Max	Min	Max
Exp. 1	0	0	0	0
Exp. 2	0	0	0	0
Exp. 3	0	131072	0	0
Exp. 4	0	131072	0	0
Exp. 5	0	131072	0	32
Exp. 6	0	131072	0	32
Exp. 7	0	131072	0	32
Exp. 8	0	131072	0	32
Exp. 9	0	131072	0	32
Exp. 10	0	131072	0	32

TABLE V displays the maximum puzzle difficulties calculated during Test ON/V/GM. As observed, the puzzle difficulty of the good requests during Z-PoW remained zero through all the experiments while it reached 32 during DDoS_KaPoW. This proves that increasing the number of the metrics didn't affect the processor load; on the contrary it enhanced the good user's experience. Finally, the puzzle difficulty of the malicious requests in Z-PoW is way higher than the malicious requests in DDoS_KaPoW and that's because Z-PoW uses 6 metrics instead of 2.

In Z-PoW and DDoS_KaPoW, no good nor malicious requests were dropped during any experiment in Test OFF/GM since the client puzzling is switched off. In both models, during test ON/V/GM there weren't any good requests dropped. TABLE VI shows the total number of the malicious requests sent and dropped during Test ON/V/GM for each experiment in both Z-PoW and DDoS_KaPoW.

In Z-PoW, when the client puzzling is on, a considerable amount of the malicious requests was dropped; even sometimes half of the requests were dropped. The number of the requests dropped is directly proportional to the total number of the sent requests. On the other hand, in DDoS_KaPoW, when the client puzzling is on, almost no malicious requests were dropped even when the number of the sent malicious requests was increased. So still the attackers will be able to access the server and dominate it at the end.

C. Fixed Puzzle Difficulty Calculation

Based on Fig. 11 and Fig. 12, in both models the average response time of the good clients, when the puzzle difficulty calculation is fixed (Test ON/F/GM), is higher than their average response time when the client puzzling is off (Test OFF/GM). This is the time cost of calculating the maliciousness score. On the other hand, the average response time of the malicious requests in test ON/F/GM is way higher than Test OFF/GM so both models succeeded at fulfilling their aim which is delaying the malicious clients by giving them harder puzzles which take more time to solve.

TABLE V. THE MAXIMUM DIFFICULTY OF BOTH MODELS DURING ON/V/GM

ON/V/GM Max Puzzle Dc	Z-PoW		DDoS_KaPoW	
	Good Requests	Malicious Requests	Good Requests	Malicious Requests
Exp. 1	0	3764768	0	12
Exp. 2	0	3764768	0	12
Exp. 3	0	3764768	0	12
Exp. 4	0	3764768	0	12
Exp. 5	0	3764768	0	32
Exp. 6	0	3764768	0	12
Exp. 7	0	3764768	32	32
Exp. 8	0	3764768	32	12
Exp. 9	0	885780	32	32
Exp. 10	0	3764768	32	12

Fig. 13 displays the average response time of the good and the malicious requests, in Z-PoW and DDoS_KaPoW, when the puzzle difficulty calculation is fixed (Test ON/F/GM). The average response time of the good requests of both models is almost the same with very few changes. Furthermore, the average response time of the malicious requests of Z-PoW is way higher than DDoS_KaPoW's. So, using more metrics helped delaying the malicious users and increasing their average response time.

During test ON/F/GM the minimum puzzle difficulty a user can get is 0 and the maximum puzzle difficulty, based on equation (2), is 500000 in Z-PoW and 50 in DDoS_KaPoW since the score used, after exceeding the predefined threshold, is equal to 10.

Based on TABLE VII, both models succeeded at preventing the attackers from accessing the server. Thanks to using more metrics, Z-PoW succeeded at preventing more malicious users and dropping their requests

D. DDoS_KaPoW vs Z-PoW vs KaPoW Guestbook

We simulated KaPoW Guestbook's model like Z-PoW's except that: one machine was acting as the server and only two client machines were used (one acting as the good clients and the other acting as the malicious ones) since it's a forum spam attack. This attack was launched 3 times, each time the number of consoles used by the attacker and the number of the sent requests were changed as shown in TABLE VIII.

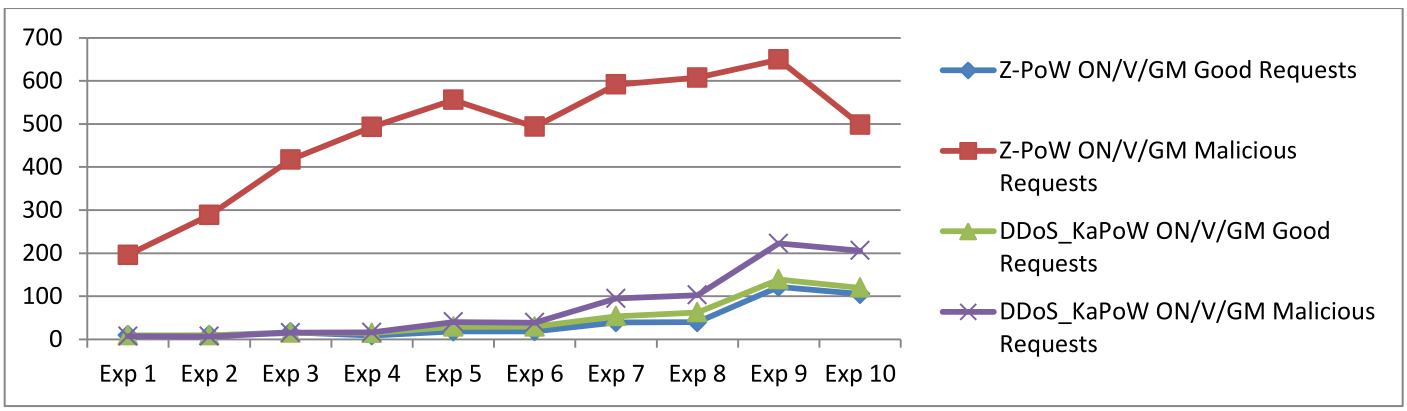

Fig. 10. Average Response Time of Both Models during Test ON/V/GM

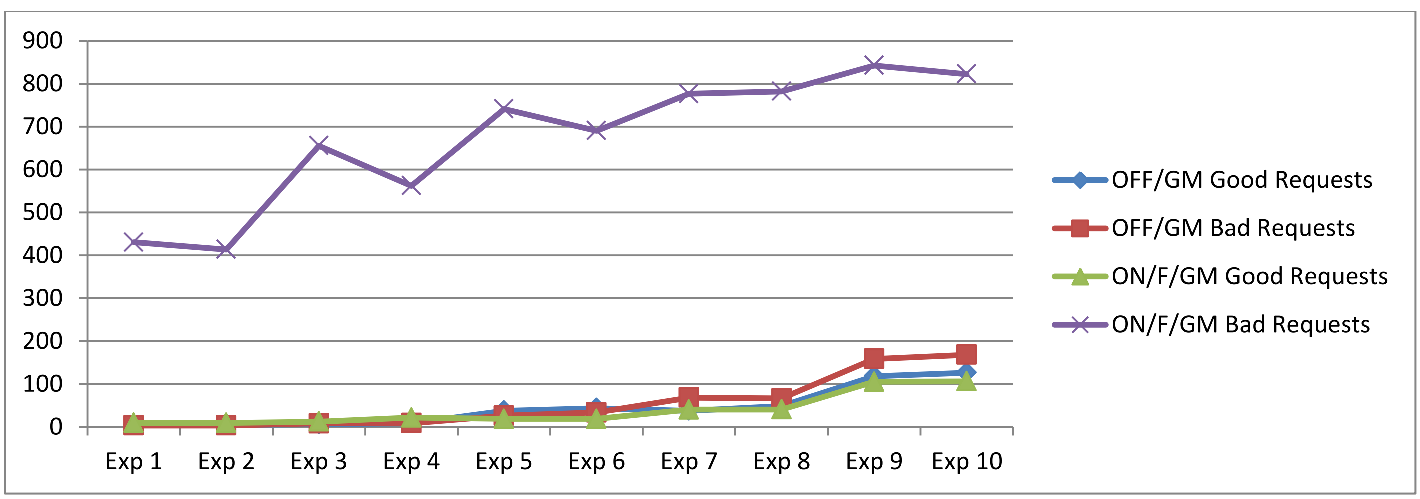

Fig. 11. Z-PoW's Average Response Time during Tests OFF/GM and ON/F/GM

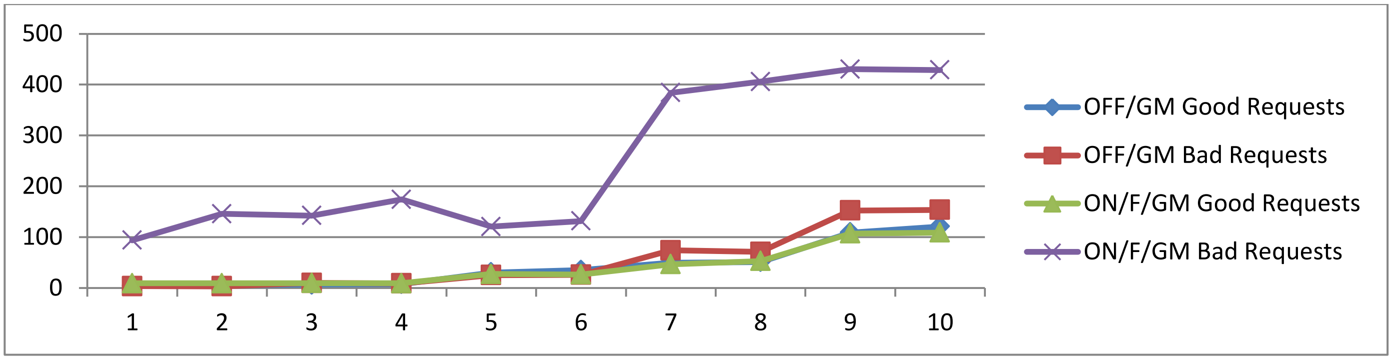

Fig. 12. DDoS_KaPoW's Average Response Time during Tests OFF/GM and ON/F/GM

TABLE VI. NUMBER OF DROPPED MALICIOUS REQUESTS OF BOTH MODELS DURING TEST ON/V/GM

ON/V/GM Malicious Requests	Total Requests sent	Z-PoW Dropped Requests	DDoS_KaPoW Dropped Requests
Exp. 1	255	20	0
Exp. 2	255	43	0
Exp. 3	510	126	0
Exp. 4	510	196	0
Exp. 5	1005	501	0
Exp. 6	1005	430	0
Exp. 7	2010	1045	0
Exp. 8	2010	1094	0
Exp. 9	4020	2418	2
Exp. 10	4020	1628	1

TABLE VII. NUMBER OF DROPPED MALICIOUS REQUESTS OF BOTH MODELS DURING TEST ON/F/GM

ON/F/GM Malicious Requests	Total Requests sent	Z-PoW Dropped Requests	DDoS_KaPoW Dropped Requests
Exp. 1	255	33	0
Exp. 2	255	39	10
Exp. 3	510	243	16
Exp. 4	510	184	9
Exp. 5	1005	704	24
Exp. 6	1005	636	45
Exp. 7	2010	1628	678
Exp. 8	2010	1611	724
Exp. 9	4020	3629	1502
Exp. 10	4020	3448	1539

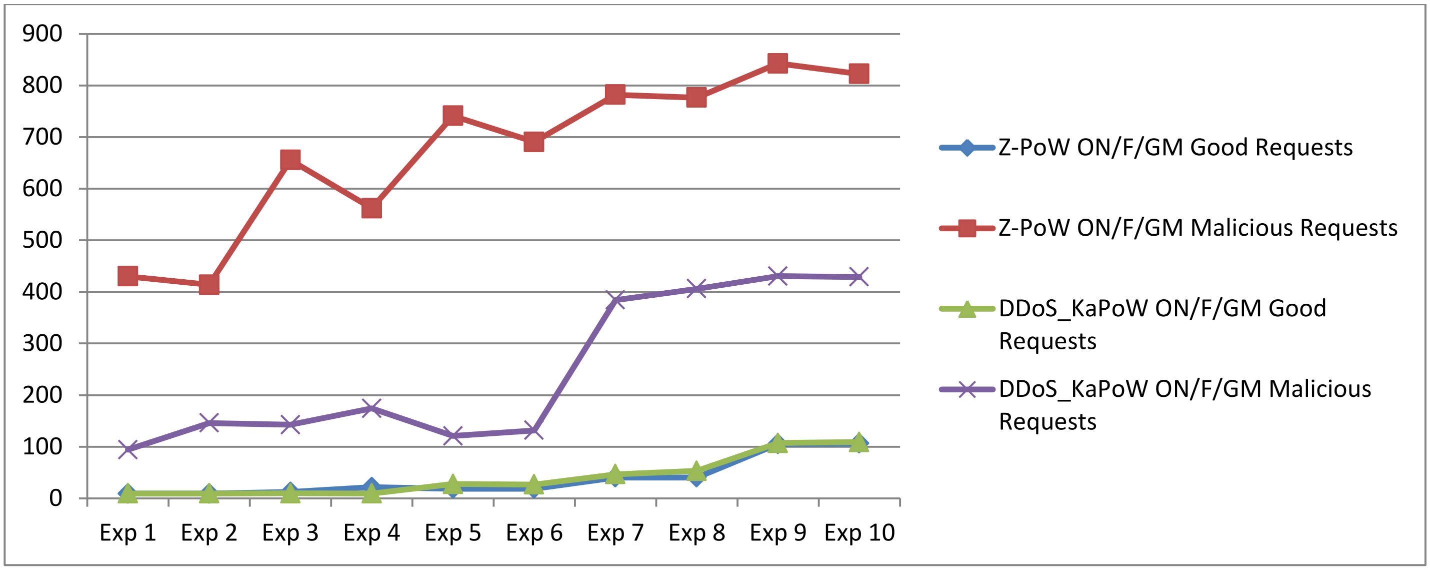

Fig. 13. Average Response Time of Both Models during Tests ON/F/GM

TABLE VIII. PERCENTAGE OF DROPPED REQUESTS IN DDOS_KAPOW, Z-POW AND KAPOW GUESTBOOK DURING TEST ON/V/GM

Exp.#	DDoS_KaPoW (5 consoles)		Z-PoW ON/V/GM (5 consoles)		KaPoW Guestbook ON/V/GM (2 consoles)		KaPoW Guestbook ON/V/GM (5 consoles)		KaPoW Guestbook ON/V/GM (1 console)	
	Total malicious	% of Dropped	Total malicious	% of Dropped	Total malicious	% of Dropped	Total malicious	% of Dropped	Total malicious	% of Dropped
1	255	0%	255	7.84%	250	0.80%	140	5%	140	10.71%
2	255	0%	255	16.86%	250	3.20%	140	2.85%	140	9.28%
3	510	0%	510	24.70%	510	20.50%	280	10.71%	280	33.57%
4	510	0%	510	38.43%	510	21.56%	280	5.71%	280	20%
5	1005	0%	1005	49.85%	1000	50.90%	550	23.09%	550	52.36%
6	1005	0%	1005	42.78%	1000	50.80%	550	25.81%	550	53.45%
7	2010	0%	2010	51.99%	2000	68.05%	1100	50.63%	1100	65.90%
8	2010	0%	2010	54.42%	2000	66.55%	1100	50%	1100	68.36%
9	4020	0.04%	4020	60.14%	4000	74.50%	2200	70.22%	2200	74.86%
10	4020	0.02%	4020	40.49%	4000	57.37%	2200	51.13%	2200	57.18%

TABLE VIII shows the percentage of the dropped malicious requests in each experiment when the client puzzling is on during the simulation of Z-PoW, DDoS_KaPoW and KaPoW Guestbook. As listed, the client puzzling dropped more malicious requests and defended DDoS attack better when the number of used metrics was increased. Almost both Z-PoW and KaPoW Guestbook have the same behavior with slightly differences which indicates that the client puzzling algorithm has comparable performance in defending against both DoS and DDoS, but it needed more metrics to defend the DDoS attacks.

VII. CONCLUSION

DDoS attacks are still considered a big threat for big companies. Although there is no 100% security but the client puzzling has proven its capability and efficiency to thwart DDoS attack through punishing the malicious clients without affecting the normal clients.

Z-PoW, is like KaPoW Guestbook, can be integrated in any application because of its modularity. It also investigates a lot of metrics to prevent the DDoS attackers from accessing the server. No good requests were dropped by applying the client puzzling which satisfies Z-PoW's goal.

Although the results of the tests with fixed difficulty are better than the tests with varied difficulty; some good clients may accidently be misinterpreted as malicious ones, hence suffer more receiving very hard puzzles.

Unfortunately Z-PoW has some deficiencies. One of them is that some normal users, who are using an automated tool or a plugin to block the referrer in the browser, will be considered as attackers because there won't be a referrer in the URL. Another flaw is the overhead added by the IP-to-country library because of the duplicate cache entries. Finally when a client has to retry a solution for the puzzle, the time taken to get a reply will be calculated from the second request sent, not from the first one.

VIII. FUTURE WORK

In order to make the malicious clients suffer more, the difficulty of their puzzle can be scaled up exponentially while the difficulty for well-behaved clients scales down linearly as suggested in [8]. Or the bad clients can be blocked after multiple spikes.

The look up of the nonce can be enhanced by using the counting bloom filters. The detection of the users coming from a ToR network or behind a proxy could be also enhanced, especially the ToR because it consumes a lot of time which is not effective.

In Z-PoW, we investigated the processor load using a Yes/No check. But in the future, a variable score can be used based on the load which will help detect a DDoS attack earlier.

The attackers can be simulated to be more sophisticated and by using General Processing Unit (GPU) cracking to facilitate solving the puzzles and compare the results with the normal clients.

Finally, Z-PoW can be enhanced by combining a Trust Model with the client puzzling. To cope up with everyday changes, Z-PoW needs to be compatible with HTML5 and IPv6. Also, DShield API changes need to be applied once they are done.

References

[1] S. Mansfield-Devine, "DDoS: threats and mitigation," Network Security, pp. 5-12, December 2011.

[2] D. J. Nazario, "DDoS attack evolution," Network Security, 15 July 2008.

[3] T. L. a. D. H. Steven Simpson, "Identifying legitimate clients under distributed denial of service attacks," in Fourth international conference on network and system security, 2010.

[4] D. D. C. a. S. Landau, "The problem isn't attribution, it's multistage attacks," in ACM Re-Architecting the Internet Workshop (ReArch), Philadelphia, 2010.

[5] M. Yoon, "Using whitelisting to mitigate DDoS attack on critical internet sites," IEEE Communications Magazine, July 2010.

[6] M. M. a. J. C. M. Ellie Bursztein, "Text-based CAPTCHA strengths and weaknesses," in Proceedings of the 18th ACM conference on Computer and Communications Security, Chicago, illinois, USA, 2011.

[7] D. L. a. L. Camp, "Proof of work can work," Fifth Workshop pn the Economics of Information Security, 2006.

[8] P. N. a. J. L. Tuomas Aura, "DoS resistant authentications with client puzzles," 8th International workshop on Security Protocols, pp. 170-177, April 2000.

[9] P. M. N. P. S. a. B. W. Liquin Chen, "Security notions and generic constructions for client puzzles," Mitsuri Matsui, editor, Advances in Cryptology - Proceedings ASIACRYPT 2009. LNCS, Springer (2009), vol. 5912, pp. 505-523, 2009.

[10] D. S. A. C. a. H. L. Suriadi Suriadi, "Defending web services against denial of service attacks using client puzzles," in IEEE ICWS "International Conference on Web Services", 2011.

[11] D. D. a. A. Stubblefield, "Using client puzzles to protect TLS," in 10th conference on USINEX Security Symposium, Washington, 2011.

[12] J. J. O. F. R. S. D. J. a. C. A. G. Jeff Green, "Reconstructing hash reversal based proof of work "PoW" schemes," in LEET'11 Proceedings on the 4th USENIX conference on LArge-scale exploits and emergent threats, Boston, 2011.

[13] D. a. W.-C. F. Tien Le, "KaPoW plugins: protecting web applications using reputation-based proof-of-work," WebQuality 2012, April 2012.

[14] E. K. a. W.-C. Feng, "Mod_kaPoW: protecting the web with transparent Proof-of-Work," IEEE INFOCOM, p. 16, 2008.

[15] E. K. a. W.-C. Feng, "Mod_kaPoW: mitigating DoS with transparent proof-of-work," in The 3rd International Conference on Emerging Networking Experiments and Technologies (CONExT), 2007.

[16] E. K. a. W.-C. Feng, "KaPoW webmail: effective disincentives against spam," in CEAS 2010 - 7th Annual Electronic messaging, Antiabuse and Spam conference, Washington, 2010.

Rule Based Approach for Arabic Part of Speech Tagging and Name Entity Recognition

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***Abstract*—The aim of this study is to build a tool for Part of Speech (POS) tagging and Name Entity Recognition for Arabic Language, the approach used to build this tool is a rule base technique. The POS Tagger contains two phases:The first phase is to pass word into a lexicon phase, the second level is the morphological phase, and the tagset are (Noun, Verb and Determine). The Named-Entity detector will apply rules on the text and give the correct Labels for each word, the labels are Person(PERS), Location (LOC) and Organization (ORG).**

Keywords—POS; Speech tagging; Speech recognition; Text phrase; Phrase; NLP

I. Introduction

Natural Language Processing (NLP) is a field of computer science, artificial intelligence, and linguistics concerned with the interactions between computers and human (natural) languages. NLP is related to the area of human–computer interaction. Many challenges in NLP involve natural language understanding; that is, enabling computers to derive meaning from human or natural language input, while others involve natural language generation [1].

The objective of this study is to contributetothe existing literature body of building atoolfor POS and Name Entity Recognition for Arabic language.

1) Part of speech

Part of speech tagging (POST) is also known as POS tagging, word classes, morphological classes,lexical tags or just tagging as a process that aims to assign a specific tag to each word of a sentence to indicate the function of that word in a specific context ,the suitable tag is chosen from a set of tags based on some rules, examples of part of speech are: nouns ,verbs, pronouns, prepositions ,adverbs and other tags, the results of part of speech are for many applications such as speech recognition, natural language parsing,information retrieval, information extraction, question answering, text to-speech conversion, machine translation, grammar correction and many more [2].

POS tagging is one of the tools and the components for infrastructure to Natural Language Processing of a given language. POS tagging is necessary in many fields such as: text phrase, syntax, semantic analysis and translation [3].

2) POS-tagging techniques

There are many techniques that may be used separately or with each other for tagging words to its classes ,the most famous methods are Rule-based, stochastic and transformation (hybrid) method:

Rule-Based Tagging: Algorithm for assigning part of speech based on two stages, the first stage uses a lexicon (dictionary) to assign each word a list of potential parts of speech, the second stage uses a huge list of hand-written disambiguation rules to winnow down this list to a single part of speech for each word [2].

Stochastic Tagging: The idea behind this approach is to pick the most likely tag for this word, in this method we need a tagged corpus to get probabilities about the ambiguous word, hidden Markov model algorithm is an example of the this technique [2].

Transformation-Based Tagging: The is an approach which combines Rule-based and Stochastic technique ,like the Rule-based, TB is based on rules to specify the tag for each ambiguous word but like Stochastic Tagger, in which rules are automatically induced for data [2].

3) Name Entity Recognition

Named Entity Recognition (NER) is a sub problem of information extraction and involves processing structured and unstructured documents and identifying expressions that refer to peoples, places, organizations and companies. NER is a fundamental task and it is the core of natural language processing (NLP) system. NER involves two tasks, which are: firstly the identification of proper names in text, and secondly the classification of these names into a set of predefined categories of interest, such as: persons,organizations, locations, date and time expressions [4].

a) Name Entity Recognition techniques

Hand-made Rule-based: focuses on extracting names using lots of human-made rules set. Generally the systems consist of a set of patterns using grammatical syntactic and Orthographic features in combination with dictionaries [4].

Machine Learning-based: NER system, the purpose of Named Entity Recognition approach is converting identification problem into a classification problem and employs a classification statistical model to solve it. In this type of approach, the systems look for patterns and relationships into text to make a model using statistical models and machine learning algorithms. The systems identify and classify nouns into particular classes using machine learning algorithms [4].

Hybrid Based: this technique is combined the rule based and machine learning-based and make new methods using strongest points from each method[4].

II. Literature Review

Mohamed and Kubler (2010) presented a method for POS tagging for Arabic language without segmentation which would be unrealistic for naturally occurring Arabic. Developed approach which used the full POS tagset. the resultsfor experiments suggest that the segmentation isn't very important in POS tagging, reached the best results in tagging for known and unknown word, the worst result of the segmentation-based approach is its low accuracy on unknown words [5].

Hadni et al (2013) proposed an efficient and accurate POS Tagging technique for Arabic language by using hybrid approach. Due to the ambiguity issue, Arabic Rule-Based method suffers from misclassified and unanalyzed words. To overcome these two problems, they presented a Hidden Markov Model (HMM) matched with Arabic Rule-Based method. The proposed technique used different contextual information for the words, this method tested with two corpora: the Holy Quran Corpus and Kalimat Corpus for undiacritized Classical Arabic language [6].

Elhadj(2009) presented the development of an Arabic part-of-speech tagger that can be used for analyzing and annotating traditional Arabic texts, especially the Quran text. His project related to the computerization of the Holy Quran which was to build a textual corpus of the Holy Quran, he focused in this work on its annotation by developing and using an appropriate tagger. The developed tagger employed an approach that combines morphological analysis with Hidden Markov Models (HMMs) based-on the Arabic sentence structure. The morphological analysis is used to reduce the size of the tags lexicon by segmenting Arabic words in their prefixes, stems and suffixes. Each tag in this system is used to give all possible state of the HMM and the transitions between tags are governed by the syntax of the sentence. A corpus of some traditional texts, extracted from Books of third century (Hijri), is manually morphologically analyzed and tagged using their developed tag set [7].

Umansky (2010) presented a web-based algorithm for the task of POS tagging of unknown words (words appearing only a small number of times in the training data of a supervised POS tagger). If a sentence is containing an unknown word that tagged by a trained POS tagger, this algorithm collects from the web contexts that are partially similar to the context of an unknown word in sentence, which are then used to compute new tag assignment for unknown word, this algorithm enables fast multi-domain unknown word tagging [8].

Aboaoga and Ab Aziz (2013) presented a rule-based approach for recognition Arabic Named Entity. The goal of this paper is to use the rule based approach for recognizing the named entities that include person names in economic, politic and sport domain. The method consists of three main steps: pre-processing, automatic named entity tagged and applying the rules. The method had been applied on Arabic corpus of three domains (politic, economic and sport) to recognize the named entity (person name) in the text. Then, the evaluation method has been used to compute the performance measure for each domain [9].

Oudah and Shaalan (2013) presented a hybrid approach for name entity recognition, and this technique contains two levels: The first level is the rule base which used to produce name entity labels based on lists of name entity keywords and contextual rules.The second level is the Machine Learning based intended to make use of rule-based component's name entity decisions as features aiming at enhancing the overall performance of the name entity recognition task [10].

Elsebai et,al (2009) presented a rule based approach for name entity recognition, the system consists of two components the first is GATE (General Architecture for Text Engineering) and the second is BAMA (Buckwalter Arabic Morphological Analyzer) the GATE used to perform tokenization and then annotate the text by highlighting those words that belong to the Introductory Verb List and Introductory word List lists [11].

Then the BAMA used to perform the input word and returns the stem rather than the root then they used a set of keywords to guide them to the phrases that probably include person names [11].

III. System Architecture

1) POS Tagger

In this project we have used the rule base to tagging the Arabic text, the proposed system(as shown below) consists of two phases : The first phase is the lexicon analyzer which contains all Arabic particles including prepositions, adverbs, conjunctions, interrogative Particles, exceptions, and interjections. The second phase is a morphological phase which uses morphological information such as the patterns of the word and its affixes (such as prefixes, suffixes and infixes) to presume the class of the words.

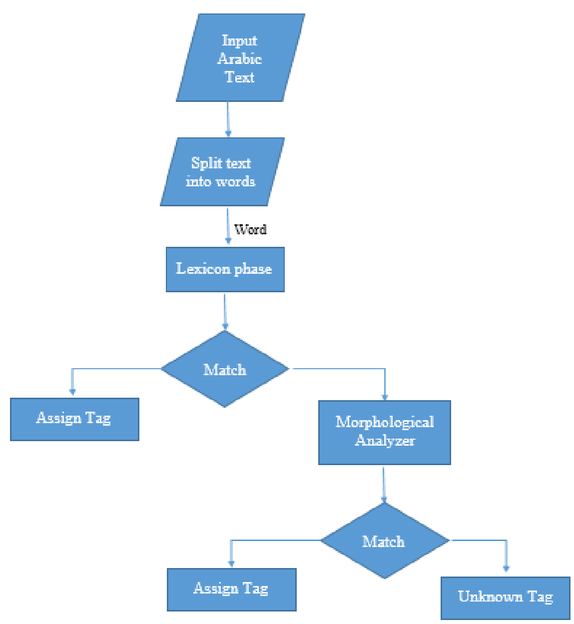

Fig. 1. The Architecture of the Tagging System

As shown in figure 1 the tagging system reads an Arabic text then splits it into words after that it takes every word and put it into the first level (Lexicon phase), in this case if it exists we return the corresponding tag, if not; the word is transferred to the second phase (Morphological phase). When completing processing the word, if it either matches, it returns the presumed tag; otherwise the tag is Unknown.

a) Lexicon phase

In this phase and after the text is split into words,the lexicon holds all Arabic fixed words and particles (prepositions, adverbs, conjunctions, interrogative particles, exceptions, questions and interjections), and every word is searched in the lexicon if it is found, the corresponding tag is returned, if it is not found in the lexicon; then it moves to the next phase (Morphological phase).

b) 1.2 The Morphological Phase

As we know, the Arabic language is more complicated because it has the largest number of possible affixes (especially prefixes and suffixes), Arabic possesses, and a large number of derivational.

In the Arabic language there are many signs that indicate if the word is a noun or a verb, some patterns in words are used with verbs and others are used with nouns, and some patterns are used for both verbs and nouns.

The information from affixesdoesn not help us to determine the exact word classification within the two major categories nouns and verbs. Certain prefixes, suffixes or infixes come with certain classes of words, the followings are some of hand-written rules to classify a word into a noun or a verb or Particles:

Rule 1: the following prefixes "كال", "بال", "فال", "وال" if it comes in the beginning of a word map it refers to Noun class.

Rule 2: the following suffixes "ائي","ائك","ائه","اؤك","اؤه","اءك","اءه","هما","كما" if it comes in the end of a word map itrefers to Noun Class.

Rule 3: the following prefixes "سي","ست","سن","سأ","سا","لا","لأ","لن","لت","لي" if it comes in the end of a word map itrefers toVerb class.

Rule 4: the following suffixes "ي", "ه", "ك", "ا", "ن", "و" if it comes in the end of a word map itrefers to Verb class.

Rule 5: if the word has the pattern (فعلى, فعول, فعاء) map it to Noun class.

Rule 6: if the word ends with "ات" map it to Noun class.

Rule 7: if the word end with "ون, ين"but starts with "ي" or "ن" map the word to Verb class.

Rule 8: if the word ends with "ون, ين" and doesn't start with "ي" or "ن" map the word to Noun class.

Rule 9: if the word has the pattern(مفاعل,مفعيل,مفعال,مفتعل,منفعل,مفعول,متفعل,مفعلل) map it to Noun class.

Rule 10: if the word has the pattern (فعاليل, أفاعيل, مفاعيل, فواعيل) map it to Noun class.

Rule 11: if the word has the pattern (استفعل, افعوعل) map it to Verb class.

2) The Name Entity Detector

The second subsystem in our project is the Name Entity Recognition, we have used the rule base approach to label the Arabic text, each word is labeled with any of the three labels Person (PERS), Location (LOC) and Organization (ORG).

The data set is three lists, the first is for person names and contain 4030 word, the second is for location names and contain 2193 words, the third is for organization names and contain 268 words, thearchitecture of the name entity system is shown in the figure below:

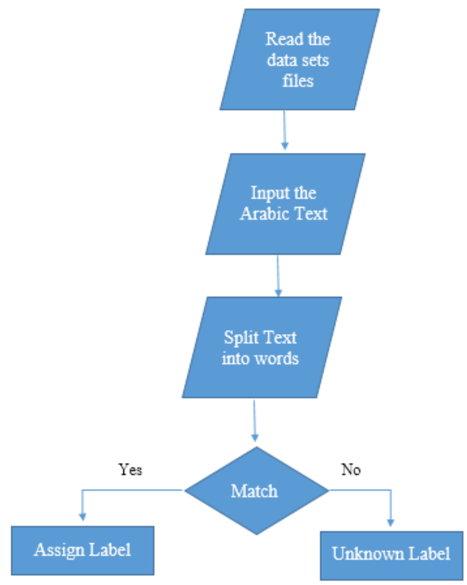

Fig. 2. The Architecture of the Name Entity System.

First the system reads the data sets that contain the person, location, organization names and stores these names, then the system reads the Arabic text and splits it into words

After that the system will apply the rules on the words and if they match then the label will be assigned to that word, if not, the label will be Unknown.

Here are some examples how the name entity detector works:

If we take the country name "المملكة الاردنية الهاشمية" this country name consists of three words so the system takes this name as one word give it LOC label.

Another example is the "الوكالة الدولية للطاقة الذرية" this organization name consists of four words, the system will take this name as one word and give it ORG Label.

If we take the person name "فلاديمير بوتين" this person name consists of two words the system take this name as one words and give it PERS Label.

If we take the person name "خالد بن الوليد"this person name consists of two name and separate them with the word "بن" so the system checks if two person name separate between them with " بن" and give it the PERS Label.

IV. Experimental Results

First the POS tagger was tested on a file that contains 793 word; the result shows that the tagger successfully tagged 679 words. However, the name entity detector was tested on a file that contains 490 words and successfully tagged 480 word.

Here som examples of the POS Tagger and name entity detector :

TABLE I. Some of Result by POS Tagger

الطيبون_N يغرسون_V الجمال_N داخل_N الروح_N لا_DET اراديا_N	الطيبون يغرسون الجمال داخل الروح لا اراديا
ليس_V الفخر_N أن_DET تقهر_V قويا_N بل_DET الفخر_N أن_DET تنصف_V ضعيفا_N	ليس الفخر أن تقهر قويا بل الفخر أن تنصف ضعيفا
عباد_N الرحمن_N الذين_N يمشون_N على_DET الأرض_N	عبادالرحمنالذينيمشونعلىالأرض
لن_DET تنالوا_V البر_N حتى_DET تنفقوا_V مما_N تحبون_V	لنتنالواالبرحتىتنفقوامماتحبون
علمتني_V الدنيا_N أن_DET أعفو_V عن_DET المخطئ_N	علمتنيالدنياأنأعفوعنالمخطئ

TABLE II. Some of Result by Name Entity Detector

صائب عريقات-PERS يقول ان الاصرار الفلسطيني على التصويت في مجلس الامن-ORG كان رسالة الى واشنطن-LOC	صائب عريقات يقول ان الاصرار الفلسطيني على التصويت في مجلس الامن كان رسالة الى واشنطن
صحيفة الغارديان-ORG البريطانية ترى ان ازمات 2015 السياسية والامنية والاقتصادية ستكون مترابطة ولا يمكن فصلها في عصر العولمة والتقلبات	صحيفة الغارديان البريطانية ترى ان ازمات 2015 السياسية والامنية والاقتصادية ستكون مترابطة ولا يمكن فصلها في عصر العولمة والتقلبات
تعرصت الاثار السورية في محافظة ادلب-LOC شمال سوريا-LOC للدمار والتخريب	تعرصت الاثار السورية في محافظة ادلب شمال سوريا للدمار والتخريب
السفير الفلسطيني في الامم المتحدة-ORG يؤكد تسليم بلاده وثيقة للانضمام للمحكمة الجنائية الدولية ويقول ان فلسطين-LOC ستلجا للخيار القانوني لمحاسبة اسرائيل-LOC	السفير الفلسطيني في الامم المتحدة يؤكد تسليم بلاده وثيقة للانضمام للمحكمة الجنائية الدولية ويقول ان فلسطين ستلجا للخيار القانوني لمحاسبة اسرائيل
أفاد مراسل الجزيرة-ORG في لبنان-LOC بمقتل ثلاثة من عناصر حزب الله-ORG وعدد من جنود الجيش السوري في مواجهات مع جبهة النصرة في محيط بلدة فليطة السورية المحاذية للأراضي اللبنانية	أفاد مراسل الجزيرة في لبنان بمقتل ثلاثة من عناصر حزب الله وعدد من جنود الجيش السوري في مواجهات مع جبهة النصرة في محيط بلدة فليطة السورية المحاذية للأراضي اللبنانية.

V. Conclusions and Future Work

In this paper the Rule Based Approach used for the Part Of Speech Tagging and Name Entity Recognition were tested. The POS Tagger contains two phases first the lexicon phase and the second Morphological phase, the name entity applies rules on Arabic text to extract person names, location and organization and give for each of them their labels. Future work will focus in increasing the tag set of the tagger and increasing the labels of the name entity detector, as well as the rules of tagger and Name Entity detector.

VI. References

[1] B Bataineh and E.Bataineh, An Efficient Recursive Transition Network Parser for Arabic Language, *Proceedings of the World Congress on Engineering* 2009 Vol II WCE 2009, July 1 - 3,(2009), London, U.K.

[2] J.H Martin and D.Jurafsky, D., Speech and language processing., *International Edition*(2010).

[3] A. AL-Taani and S.Abu Al-Rub, A Rule-Based Approach for Tagging Non-Vocalized Arabic Words, *The International Arab Journal of Information Technology*, Vol. 6, Issue. 3(2009).

[4] A.Mansouri, S.Lilly Affendey and A.Mamat, Named Entity Recognition Approaches, *International Journal of Computer Science and Network Security*, VOL.8 Issue.2,(2008).

[5] E.Mohamed and S.K¨ubler , "Is Arabic part of speech tagging feasible without word segmentation?." Human Language Technologies: *The 2010 Annual Conference of the North American Chapter of the Association for Computational Linguistics*. Association for Computational Linguistics, (2010).

[6] M.Hadni, S. Ouatik, A.Lachkar and M.Meknassi, Hybrid Part-Of-Speech Tagger for Non-Vocalized Arabic Text, *International Journal on Natural Language Computing (IJNLC)* Vol. 2, Issue.6, (2013).

[7] Y.Elhadj.Statistical Part-of-Speech Tagger for Traditional Arabic Texts,*Journal of Computer Science Vol.5*, *Issue* 11, pp.794-800, (2009) ,ISSN 1549-3636,© 2009 Science Publications.

[8] S.Umansky-Pesin, R.Reichart and A.Rappoport,, A multi-domain web-based algorithm for POS tagging of unknown words. *Proceedings of the 23rd International Conference on Computational Linguistics: Posters*. Association for Computational Linguistics, (2010).

[9] M.Aboaoga and M. Ab Aziz, “Arabic Person Names Recognition By Using A Rule Based Approch”, *Journal of Computer Science*, Vol. 9, Issue 7, pp. 922-927, (2013) ISSN: 1549-3636© 2013 Science Publications.

[10] M.Oudeh and K.Shaalan, K., Person Name Recognition Using Hybrid Approach, *lecture Notes n Computer Science, Natural Language Processing and Information Systems, Springer Berlin Heidelberg*, vol. 7934, pp. 237-248.

[11] A.Elsebai, F. Meziane and F.Belkredim, A Rule Based Persons Names Arabic Extraction System, *Communications of the IBIMA*Vol.11, (2009) ISSN: 1943-7765.

Resource Utilization in Cloud Computing as an Optimization Problem

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***Abstract*—In this paper, an algorithm for resource utilization problem in cloud computing based on greedy method is presented. A privately-owned cloud that provides services to a huge number of users is assumed. For a given resource, hundreds or thousands of requests accumulate over time to use that resource by different users worldwide via the Internet. A prior knowledge of the requests to use that resource is also assumed. The main concern is to find the best utilization schedule for a given resource in terms of profit obtained by utilizing that resource, and the number of time slices during which the resource will be utilized. The problem is proved to be an NP-Complete problem. A greedy algorithm is proposed and analyzed in terms of its runtime complexity. The proposed solution is based on a combination of the 0/1 Knapsack problem and the activity-selection problem. The algorithm is implemented using Java. Results show good performance with a runtime complexity *O((F-S)nLogn)*.**

Keywords—Activity Selection; NP-Complete; Optimization Problem; Resource Utilization; 0/1 Knapsack

I. Introduction

The term cloud computing has become a buzzword in the recent years due to the publicity and widespread of the term in all aspects of life. Cloud computing in its basic form is a model of on-demand provisioning of computing resources to users [1]. Resources such as computers, network servers, storage, applications, services, etc. are shared and reusable among users, this is referred to as Multi-tenancy [2]. Clouding has a great influence on the cost of operation of information technology (IT) infrastructure. Companies no longer need to spend on building on-premises IT departments to support their operations. Adopting the pay-as-you-go strategy, i.e. pay only for resource usage, will cut the costs of IT operations which include maintenance, employment, training, etc. In its simplest form, provisioning of resources via clouds is similar to the way of obtaining electricity from power stations without the need for everyone to establish his privately-owned station [3].

Resources lie at the heart of cloud computing. Resource utilization (pooling) is an important topic in the field of computer science, yet it is a hot research area. The need for resource utilization never stops as long resources are limited compared to the increasing demand on computers and computing. Resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand [1].

Internet plays an important role in signifying the importance of resources. The demand on the Internet and the resources are ever increasing. The advent of cloud computing encouraged companies and computer professionals to use more and more resources even if they are not available on their premises. However, this might incur fees to be paid by those users, on the other hand, service providers have to find how to best utilize their resources so as they can serve more users during specific operation time. The main idea of cloud computing is about providing (leasing) services to users. The service providers can think in leasing their services in ways that maximize their overall profit.

In this paper, a privately-owned cloud that provides services to a huge number of users is assumed. For a given resource, hundreds or thousands of requests accumulate over time to use that resource by different users worldwide via the Internet. The main concern is to find the best utilization schedule for a given resource in terms of profit obtained by utilizing that resource, and the number of time slices during which the resource will be utilized. A prior knowledge of the requests to use that resource is assumed.

The proposed algorithm, based on a greedy method, is a combination between the solutions of two different problems, the Knapsack Problem and the Activity-Selection Problem. Based on these two techniques, this utilization problem is an NP-Complete problem.

After formalizing the problem and defining it, a greedy algorithm to solve that problem is proposed. The proposed algorithm is then analyzed in terms of runtime complexity. Finally, experimental results are recorded and discussed.

The paper is organized as follows: in Section II, a sample of related work is presented. In Section III, a mathematical formulation to the problem, the proposed algorithm and a detailed discussion of algorithm design, complexity, and NP-Completeness of the problem are introduced. In Section IV, the experimental results are discussed. Finally, conclusion and future work are presented in sections V and VI.

II. Related Work

Maya Hristakeva et al [4], presented a number of methods to solve the 0/1 Knapsack problem. One of the methods presented is the greedy method. At the beginning, the 0/1 Knapsack problem is identified and formalized, then a greedy algorithm is discussed, analyzed, and compared to other algorithms for different methods used in the research.

In [5], authors described an algorithm which generates an optimal solution for the 0/1 integer Knapsack problem on the NCUBE hypercube computer. Experimental data which supports the theoretical claims were provided for large instances of the one- and two-dimensional Knapsack problems.

In Knapsack problem, a number of items have to be chosen to fill the knapsack without exceeding its capacity so as the knapsack profit is maximized [6]. The 0-1 Knapsack Problem is formulated as follows:

- The knapsack (K) has a capacity C.
- The item (T) is a tuple $T < w, p >$, such that w is the weight of the item and p is the profit.
- The objective is as in (1):

$$Maximize \sum_{i=1}^{n} p_i x_i \;\; Subject\ to \sum_{i=1}^{n} w_i x_i \le c$$
$$such\ that\ x_i \in \{0, 1\}, i = 1, \dots, n \qquad (1)$$

In [7], authors considered a setting in which they organized one or several group activities for a group of agents. Their goal was to assign agents to activities in a desirable way. They gave a general model, then studied some existence and optimization problems related to their solutions. Their results were positive as they found desirable assignments that proved to be tractable for several restrictions of the problem.

The Weighted Activity-Selection problem is an optimization problem [8], and it is a variant of the Activity-Selection Problem. Components of the problem are as follows:

- An activity (A) is a tuple $A < s, f, p >$, such that s is the activity's start time, f is its finish time, and p is the profit of that activity.
- For an activity $A_i, s_i < f_i\ and\ p_i \ge 0$.
- Two activities A_i and A_j are said to be compatible if and only if $s_j \ge f_i$ or $s_i \ge f_j$.
- A feasible schedule (S) is a set $S \subseteq \{1, 2, \cdots, n\}$, such that every two distinct numbers in S are compatible.
- The profit (P) of a schedule (S) is $P(S) = \sum_{i \in S} p_i$.
- The objective is to find a schedule that maximizes the profit.

III. Algorithm

Assume a resource *R*, with a start time *S*, finish time *F*, maximum capacity *C*, and Profit per Unit of Weight *PU*. The resource R is expressed as a tuple $R < S, F, C, PU >$. The resource is connected to a network, mainly a public network like the Internet, and receives a huge number of requests. Each request Q is identified by its Id, and has a start time *S*, finish time *T*, and weight *W*. The request Q is expressed as a tuple $Q < S, F, W >$. Two requests q_i and q_j are said to be *compatible* if and only if they do not overlap, i.e. the start time of the latter must be greater than or equal to the finish time of the former.

The goal is to allocate the resource in a way that achieves *best utilization* within the following constraints:

- Maximize the profit of utilization.
- The weight of each request must not exceed the maximum capacity of the resource.
- Start and finish time of selected requests must not go beyond the boundaries of start and finish time of the resource.
- Requests must be compatible (must not overlap).

Formally, Let:

- $R < S,\ F,\ C,\ PU >$.
- Q is a set of Requests $Q = \{q_i \mid i = 1,\ 2, \dots,\ n\}$, such that $q_i < s_i, f_i, w_i >$, whereas $s_i, f_i, and\ w_i$ are the start time, finish time, and weight of request i respectively.
- $x_1, x_2, \dots, x_n$ are binary variables that indicate item selection ($x_i = 1$) or exclusion ($x_i = 0$).
- P is the total profit of utilization, W is the total weight of solution.

$$Maximize\ P = \sum_{i=1}^{n} x_i p_i\ ,\ such\ that\ W = \sum_{i=1}^{n} x_i w_i \le C$$
$$where\ p_i = w_i(f_i - s_i) \times PU, s_i \ge S, f_i \le F,$$
$$and\ x_i = \begin{cases} 1 & s_i \cap f_j = \emptyset\ and\ w_i \le C \\ 0 & otherwise \end{cases},$$
$$such\ that\ S, F, C, PU, s_i, f_i, w_i, P, W, x_i, p_i \in \mathbb{N}. \qquad (2)$$

A. Explanation

Figure 1 shows the proposed algorithm. It comprises four phases, they are: (1) filtering, (2) maximum-request selection, (3) fill-right-to-max, and (4) swipe phase. Lines 7 – 11 represent the *filtering* phase. In this phase, all requests that do not meet the constraints of the resource are filtered (removed from the request array). In other words, any request with a weight exceeds the capacity of the resources, or any request that exceeds any of the boundaries of start and finish time of the resource, is filtered.

```
Function:   MaxProfitSchedule()
Input:      ReqArr: Requests Array, C, S, F: resource capacity, start time, and finish time
Output:     Schedule: Maximum profit schedule array
1   left = S                                                                  C_1
2   right = F                                                                 C_2
3   available = C                                                             C_3
4
5   while (!ReqArr.isEmpty())                                                 C_4(K + 1)
6   {
7       for each (Req in ReqArr){                                             C_5K(n + 1)
8           if (Req.weight> available or Req.S< left or Req.F> right){        C_6Kn
9               remove Req from ReqArr                                        C_7Kn
10          }
11      }
12
13      sort (non-increasing order) ReqArr by profit                          KnLogn
14  MaxReq = ReqArr[0]                                                        C_8K
15      add MaxReq to Schedule                                                C_9K
16      remove ReqArr[0] from ReqArr                                          C_10K
17      available = available - MaxReq.weight                                 C_11K
18      left = MaxReq.F                                                       C_12K
19
20      sort (non-decreasing order) ReqArr by start time                      KnLogn
21      for each (Req in ReqArr){                                             C_13K(n + 1)
22          if (Req.S>=left and Req.weight<= available){                      C_14Kn
23              add Req to Schedule                                           C_15Kn
24              remove Req from ReqArr                                        C_16Kn
25              available = available - Req.weight                            C_17Kn
26              left = Req.F                                                  C_18Kn
27          }
28      }
29
30      for each (Req in ReqArr){                                             C_19K(n + 1)
31          if (Req.S>= MaxReq.F){                                            C_20Kn
32              remove Req from ReqArr                                        C_21Kn
33          }
34      }
35      right = MaxReq.S                                                      C_22K
36      left = S                                                              C_23K
37  }
38  sort (in non-decreasing) Schedule by start time                           nLogn
39  return Schedule                                                           C_24
```

Fig. 1. The proposed algorithm with time complexity for each step

This step is necessary, as it minimized the size of the request array through different iterations of the selection process. Back to line 5, a while statement is used to keep on iterating until the request array is empty.

Lines 13 – 18 represent the *maximum-request selection* phase. It starts by sorting the request array in a non-increasing order by profit. This makes the maximum compatible request at the first location of the request array. As a result of the filtering phase, the first request is guaranteed to be compatible as long its weight is less than the capacity of the resource, or the remaining capacity in later iterations, and it does not exceed the boundaries of the start and finish time of the resource. In line 15, the request is added to the schedule, removed from the request array in line 16, its weight is deducted from the resource capacity in line 17, and set the new start time to the end time of that maximum request.

The third phase is the *fill-right-to-max* phase. Here, all the time slots to the right of the maximum request selected in the previous phase are filled. This phase starts in line 20 by sorting the request array in a non-decreasing order by start time of requests. Lines 21-23 iterate through all requests, pick up any request with weight less than the remaining capacity of the resource, and with a start time greater than or equal to the new left boundary. Until now, it is the finish time of the maximum request already selected in line 14. Finally, add this request in line 23 to the schedule. Similar to the previous phase, any request selected to be in the schedule: (1) is removed from the request array (line 24), (2) its weight is deducted again from the available resource capacity (line 25), and (3) its finish time is set temporarily to be the new resource start time (line 26).

Lines 30-35 signal the start of the *swipe* phase. The phase comprises iteration through the request array and removing all requests that have start time greater than or equal to the finish time of the maximum request. These requests are still existent in the request array because they are incompatible with either the maximum request or the request to the right of it. They are removed to resize the array and start a new iteration with a fewer number of requests. In line 35, the start time of the maximum request is set to be the new resource finish time, and in line 36, the left boundary of the resource is set back again to the original start time S.

Iterations continue until there are no remaining requests in the request array, i.e. size of the request array equals zero. The iteration will stop at that point. The schedule array will be sorted in a non-decreasing order by start time in line 39, and the schedule is returned to the calling routine.

B. Analysis

All the terms that precede line 5 are constants. Line 5 introduces the term K which is the number of iterations of the outer while loop. The loop is expected to run until the request array is empty. In the worst case, the number of iterations is equal to the number of intervals of the resource ($K = F - S$). Assuming that all requests have weights less than or equal to the capacity of the resource, each with start and finish time within the boundaries of the start and finish time of the resource, and assuming a worst-case scenario in which the maximum request, i.e. the one with the highest profit, is at the end of the request array.

According to the algorithm and the assumptions aforementioned, the filtering phase will not be applicable to the initial setting, so no items will be removed from the request array. In the maximum-request selection phase, the maximum request will be added to the schedule and removed from the request array. The third phase, fill-right-to-max, is not applicable too, as long there are no requests to the right of the maximum request that has been just selected. Similarly, the swipe phase will not be applicable, because there remains no further requests right to the maximum request that are not added to the schedule. Repeating the same steps for K times, an empty array is obtained.

The sorting of an array takes $nLogn$ time, in case of using one of the sorting algorithms of logarithmic runtimes such as the merge sort. When implementing the algorithm using Java, the `Collections.sort()` method is used which has $O(nLogn)$ runtime complexity according to Java documentation [9]. Complexity of the algorithm is evaluated as follows:

$$T(n) = C_1 + C_2 + C_3 + C_4(K+1) + C_5K(n+1) + C_6Kn + C_7Kn + KnLogn + C_8K + C_9K + C_{10}K + C_{11}K + C_{12}K + KnLogn + C_{13}K(n+1) + C_{14}Kn + C_{15}Kn + C_{16}Kn + C_{17}Kn + C_{18}Kn + C_{19}K(n+1) + C_{20}Kn + C_{21}Kn + C_{22}K + C_{23}K + nLogn + C_{24}$$

$$= C_{25} + C_{26}K + C_{27}Kn + nLogn + 2KnLogn \quad (3)$$

The largest term of equation (3) is $KnLogn$, so the effort of the algorithm is $O(KnLogn)$, As mentioned earlier $K = F - S$, thus, the effort of the algorithm is expressed as $O((F - S)nLogn)$.

The value of $F - S$ in the complexity of the algorithm is arguable in the sense whether to remove it from the equation or not. In the case of cloud computing and resource utilization, time slots can be measured in seconds or in factions of seconds. If a time slot of 1 second is assumed, for a 24-hour duty for a resource is equal to 86,400 seconds (time slots), which approximates to 84K of slots. This implies that the value $F - S$ might be influential in the calculation of the complexity of the algorithm, so the complexity is expressed as $O\big((F - S)nLogn\big)$.

C. Example

Consider a privately-owned cloud with a number of resources available to users each with a capacity C and is due to service hours starting from $S = 08{:}00$ and ending in $F = 18{:}00$. The service provider charges an amount of PU as a profit per unit of weight. Assume 15 requests with capacities less than the resource capacity (C) and random profits as shown in Fig. 2 (a).

The initial schedule for the resource utilization is shown in Fig. 2 (d). When running the algorithm that is shown in Fig. 1, the following steps will be executed:

*1) Step 1:*Sort the requests according to their profits in a non-increasing order. The result is shown in Fig. 2 (b).

*2) Step 2:*Comprises the following steps:

- Add request R_{11} which has the maximum profit to the schedule and remove it from the requests array. The schedule will look like as in Fig. 2 (d) row MRS.

- Sort the remaining requests in a non-decreasing order according to their starting times as shown in Fig. 2 (c).

3) Step 3: Select a request that can be fit after R_{11} into the schedule, i.e. its start time is equal to or greater than the finish time of R_{11}. R_2 is the selected request. The result of adding R_2 into the schedule is shown in Fig. 2 (d) row FRM. Now, R_2 must be removed from the requests array. Then, any further requests' selections must be after the finish time of R_2.

4) Step 4: Repeat step-3 for each request that follows R_2, each time changing the new start time to the selected request's finish time until no further requests can be added. Each time, the selected request is removed out of the request array. After this step R_3 and R_7 will be selected to the schedule as in Fig. 2 (c), second row labelled MRS.

5) Step 4: Repeat step-1 to step-4 until no requests can be scheduled. The final schedule will be as shown in Fig. 2 (d) row Final, with a total profit of 1630.

ID	Interval	Profit
R_1	08-09	250
R_2	13-14	200
R_3	14-16	300
R_4	12-14	500
R_5	09-12	250
R_6	11-13	180
R_7	17-18	200
R_8	15-18	450
R_9	09-13	220
R_{10}	13-16	250
R_{11}	10-14	680
R_{12}	11-14	550
R_{13}	13-15	150
R_{14}	08-12	400
R_{15}	17-18	100

(a)

ID	Interval	Profit
R_{11}	10-14	680
R_{12}	11-14	550
R_4	12-14	500
R_8	15-18	450
R_{14}	08-12	400
R_3	14-16	300
R_5	09-12	250
R_{10}	13-16	250
R_1	08-09	250
R_9	09-13	220
R_7	17-18	200
R_2	13-14	200
R_6	11-13	180
R_{13}	13-15	150
R_{15}	17-18	100

(b)

ID	Interval	Profit
R_1	08-09	250
R_{14}	08-12	400
R_5	09-12	250
R_9	09-13	220
R_6	11-13	180
R_{12}	11-14	550
R_4	12-14	500
R_2	13-14	200
R_{13}	13-15	150
R_{10}	13-16	250
R_3	14-16	300
R_8	15-18	450
R_7	17-18	200
R_{15}	17-18	100

(c)

<table>
<tr><td></td><td colspan="11">Intervals</td></tr>
<tr><td>Phase</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td></tr>
<tr><td>Initial</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>MRS</td><td></td><td></td><td colspan="4">$\boldsymbol{R_{11}}$</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>FRM</td><td></td><td></td><td colspan="4">$\boldsymbol{R_{11}}$</td><td>$\boldsymbol{R_2}$</td><td></td><td></td><td></td><td></td></tr>
<tr><td>FRM</td><td></td><td></td><td colspan="4">$\boldsymbol{R_{11}}$</td><td>$\boldsymbol{R_2}$</td><td colspan="2">$\boldsymbol{R_3}$</td><td colspan="2">$\boldsymbol{R_7}$</td></tr>
<tr><td>Final</td><td>$\boldsymbol{R_1}$</td><td></td><td colspan="4">$\boldsymbol{R_{11}}$</td><td>$\boldsymbol{R_2}$</td><td colspan="2">$\boldsymbol{R_3}$</td><td colspan="2">$\boldsymbol{R_7}$</td></tr>
</table>

(d)

Fig. 2. An example: (a) Array of 15 requests to use the resources. (b) Requests array after sorting it in a non-increasing order by requests weights. (c) The requests array after removing the request with the maximum profit and sorting it again in a non-decreasing order by the starting times of requests. (d) Resources Utilization Schedule; each row represents a phase: Initial: initial setting; MRS: Maximum-Request Selection Phase; FRM: Fill-Right-to-Max phase; Final: Final Resource Utilization Schedule

D. NP-Completeness

Proving the NP-Completeness of a certain problem represented in a language L is a two-step process. It involves [10]: (1) Prove that $L \in NP$, and (2) Prove that L *is NP-Hard*: if there exists a language L', such that $L' \in NPC$, and L is polynomially reducible to L' ($L' \leq_p L$).

To check that $L \in NP$, for the language L that doesn't have a polynomial-time solution, there must be an algorithm (A) that checks (verifies) a proposed solution in polynomial time. This algorithm is referred to as the certificate [11].

Figure 3 shows a list of known NP-Complete problems organized in a hierarchical way so as a problem in a lower level of the tree can be polynomially reduced to a problem in a higher level of the hierarchy.

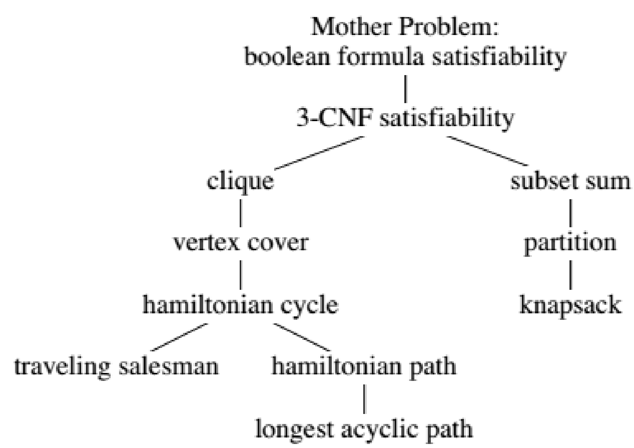

Fig. 3. A family tree of reductions [11]

Theorem 1. The resource utilization problem is an NP-Complete problem.

Proof. According to the two steps discussed earlier:

- The result of running the algorithm shown in Fig. 1 can be taken to verify that it is a solution to the resource utilization problem. An iteration through the requests in the final schedule checking that all of them are within the start and finish time of the resource working hours takes only $O(n)$ for the verification process. This means that a solution is verifiable in a polynomial time, which means that $Resource\text{-}Utilization\text{-}Problem \in NP$.
- To prove that the resource-allocation problem is NP-Hard, there must be a language (L') to which L can be polynomially reduced, that is the knapsack problem. To show that Knapsack-Problem $\leq_p$ Resource-Utilization-Problem, resource utilization must be casted to an instance of a knapsack problem to prove its NP-Hardness. Let the resource R be the knapsack and the capacity of the resource be the knapsack capacity. The objective is to fill the knapsack, or utilize the resources, with requests so as they do not exceed the capacity of the knapsack and the profit is maximized. It is clear that the resource-allocation problem is polynomially reducible to the knapsack problem, Knapsack-Problem $\leq_p$ Resource-Utilization-Problem, which means that the resource utilization problem is NP-Hard.

From the previous two steps, it is proven that the resources utilization problem is an NP-Complete problem, $Resource\text{-}Utilization\text{-}Problem \in NPC$. ■ ■

IV. Results

Tests are conducted on different datasets of sizes: 32K, 64K, 128K, 256K, 512K, 1M, 2M and 3MB. Datasets with further sizes were unable to be tested on the test PC due to memory limitations. Tests are performed on an Intel Core(TM) i5-3230M CPU with 2.60 GHz and 3 MB cache with 4 cores and 4 GB of RAM (3.86 GB is only usable). The PC runs windows 7 Enterprise edition 32-bit. The application program was written in Java. Datasets are generated by the application and saved to disk files.

Each dataset is experimented 10 times, runtime in milliseconds is recorded, and an average runtime is calculated. The parameters are set as follows: start time: 1, finish time: 86400 (number of seconds in a 24-hour period), resource capacity: 1048576, PU: 0.001. Results are shown in TABLE I.

Figure 4 shows the experimental runtimes depicted directly from TABLE I.

Figure 5 shows the chart for the asymptotic notation $O((F-S)nLogn)$, such that $S=1$ and $F=86{,}400$.

It is clear from both Fig. 4 and Fig. 5 that experimental and theoretical results converge. Many terms are removed from the asymptotic notation of the runtime complexity when calculated theoretically, and that explains the slight difference in shape between the two graphs.

TABLE I. Runtimes (in Milliseconds) of 10 Experiments Conducted on Different Sizes of Datasets

DS	Experiment 1	2	3	4	5	6	7	8	9	10	Average
64K	95.02	90.04	68.17	76.03	78.27	72.25	76.67	76.38	73.63	70.54	**77.70**
128K	256.39	205.83	204.05	197.31	200.54	199.60	208.70	204.15	199.46	201.77	**207.78**
256K	463.88	350.29	352.48	347.63	347.63	345.24	352.96	371.47	373.05	373.04	**367.77**
512K	957.36	936.62	936.57	943.66	1031.68	967.55	923.58	923.01	924.04	927.52	**947.16**
1M	2103.97	2093.14	2066.18	2126.77	2062.16	2066.81	2123.03	2079.78	2069.10	2119.20	**2091.01**
2M	4652.05	4737.74	4510.62	4931.98	4743.48	4478.73	4787.84	4678.89	4501.99	4911.64	**4693.49**
3M	9960.13	8582.96	8396.89	8766.30	8773.53	8558.79	9396.24	8603.12	9484.08	8704.05	**8922.61**

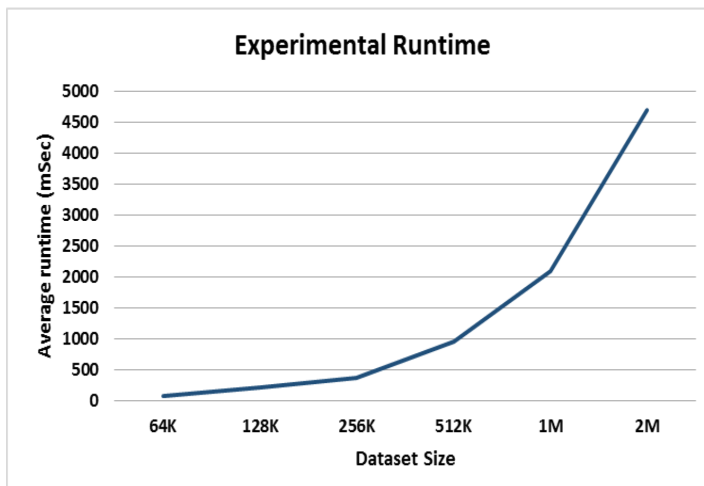

Fig. 4. Runtime chart for experimental results

Figure 6 shows the asymptotic $O(nLogn)$ complexity. To depict this graph, the same dataset sizes in the experiments need to be used, then the shapes of the graphs are compared together. This step is very important in the way it is used to prove the asymptotic notation. The controversial part in the asymptotic notation was the use of $F-S$ in the expression. Some can argue that this term is not influential in the notation. Mathematically, based on the values used above for both S and F, the difference is very high which may lead the results of comparing both notations to differ significantly.

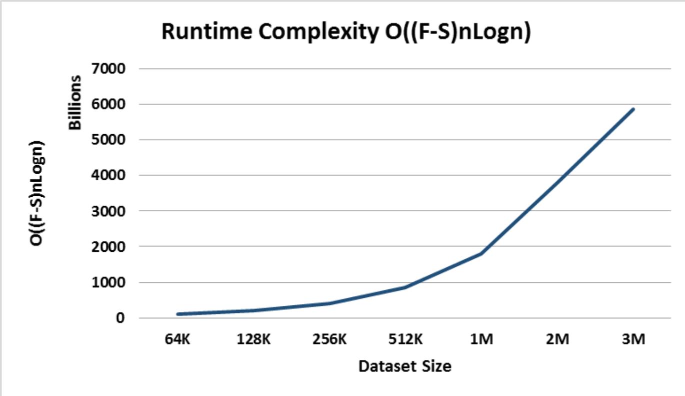

Fig. 5. Theoretical runtime graph when complexity is expressed as $O((F-s)nLogn)$

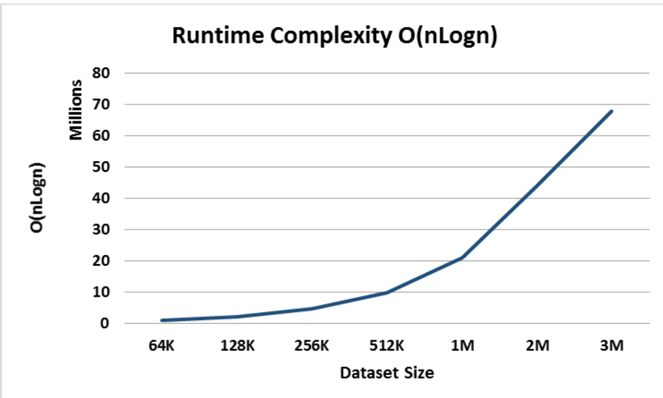

Fig. 6. Theoretical runtime graph for complexity $O(nLogn)$

From Fig. 5 and Fig. 6, it is clear that the value $F-S$ is highly influential on the overall performance of the algorithm, which means it is not possible to be removed from the runtime complexity. Thus the complexity is asymptotically expressed as $O((F-S)nLogn)$. This proves our asymptotic runtime complexity of the proposed algorithm.

V. Conclusion

In this paper, an optimization to the resources utilization problem in cloud computing is suggested. The solution is based on a combination between the 0/1 Knapsack problem and the activity-selection problem. The problem was introduced. The proposed greedy algorithm was analyzed, and then implemented using a Java program. It is proved that the problem is an NP-Complete problem. Asymptotically, the algorithm's runtime is $O((F-S)nLogn)$. Results proved the asymptotic runtime is $O((F-S)nLogn)$. An important part in that proof was whether to omit the term $F-S$ from the asymptotic notation or not by depicting two charts for the notations, one for $O(nLogn)$ and the other for $O((F-S)nLogn)$. The second notation was proved when compared to the experimental runtime results.

VI. Future Work

As a future work, the algorithm could be implemented on a supercomputer. The scheduling can be made online by using preemption to obtain better utilization and higher profits. As an addition to the currently suggested model, different pricing schemes for different periods of the working hours might be added, for example the peak time.

References

[1] P. Mell and T. Grance, "The NIST Definition of Cloud Computing, Recommendations of the National Institute of Standards and Technology," National Institute of Standards and Technology, U.S. Department of Commerce, 2011.

[2] H. AlJahdali, A. Albatli, P. Garraghan, P. Townend, L. Lau and J. Xu, "Multi-Tenancy in Cloud Computing," in 2014 IEEE 8th International Symposium on Service Oriented System Engineering, 2014.

[3] Azeez, S. Perera, D. Gamage, R. Linton and P. Siriwardana, "Multi-Tenant SOA Middleware for Cloud Computing," in 3rd International Conference on Cloud Computing, Florida, 2010.

[4] M. Hristakeva and D. Shrestha, "Shrestha, Different Approaches to Solve the 0/1 Knapsack Problem," in Midwest Instruction and Computing Symposium, 2005.

[5] L. J., S. E. and S. S., "A HYPERCUBE ALGORITHM FOR THE 0/1 KNAPSACK PROBLEM," Journal of Parallel & Distributed Computing, vol. 5, no. 4, pp. 438-456, 1988.

[6] D. Pisinger, Algorithms for Knapsack Problems, PhD Thesis, Dept. of Computer Science: Univeristy of Copenhagen, 1995.

[7] D. A., E. E., K. S., L. J., S. J. and W. G., "Group Activity Selection Problem," Lecture Notes in Computer Science, vol. 7695, pp. 157-170, 2012.

[8] V. K. Patel and M. H. Pandya, "Learning of Scheduling Algorithm with Maximum Compatible Activity or Minimum Makespan," International Journal of Engineering Development and Research (IJEDR), vol. 1, no. 2, pp. 121-124, 2014.

[9] Java Documentation, "Class Collections, Java Doc," Oracle, [Online]. Available: http://docs.oracle.com/javase/7/docs/api/java/util/Collections.html. [Accessed 28 12 2015].

[10] T. H. Cormen, C. E. Leiserson, R. L. Rivest and C. Stein, Introduction to Algorithms, 3rd ed., The MIT Press, 2009.

[11] T. H. Cormen, Algorithms Unlocked, The MIT Press, 2013.

Improvement of Persian Spam Filtering by Game Theory

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***Abstract*—There are different methods for dealing with spams; however, since spammers continuously use tricks to defeat the proposed methods, hence, filters should be constantly updated. In this study, Stackelberg game was used to produce a dynamic filter and the relations between filter and adversary were modelled as a turn game in which there is a leader and a follower. Then, an attempt was made to solve the game as an optimization program via the evolutionary stable strategy (ESS). The dataset used in the study for evaluating and analyzing the proposed method was a real dataset including the emails of four users' personal emails. The results of the conducted evaluations and investigations indicated that the proposed method had an 8% improvement over the three-class classification method and a 0.8% improvement over the ESS-based equilibrium point method.**

***Keywords*—Spam Filtering; Game theory; Stackelberg game; Evolutionary Stable Strategy; Email Classification; Stackelberg equilibria**

I. Introduction

misuse of email is becoming an increasingly serious problem for both individuals and organizations, The occurrence of more and more spam has made up great threat to the security of the internet, it not only occupies numerous network bandwidth and causes great network resources, but also affects people's normal life. Since spammers know some ways not to be recognized, techniques are discussed which may detect and filter spams out of legal emails; indeed, such techniques and methods can be applied on words, phrases or specific fields. Nevertheless, even such good and acceptable filters sometimes fail to accurately classify unsolicited messages. The two chief categories in technique classification are list-based methods and content-based methods. Recently, content-based methods have attracted more attention and interest; The reason for the less popularity of list-based methods in comparison to content-based ones is that list-based methods have fixed rules and regulations which need to be updated frequently. Spammers usually make some changes on spams so that filter would identify them as regular and normal mails.

In this study, the behavior and relation between adversary (spammer) and spam filter (classifier) was investigated. In the method introduced in the present study, relation between spammer and filter modelled as a sequential Stackelberg game and filters detect spams by learning the adversary's behavior. On the other hand, adversary try to deceive filters by learning their parameters. For finding the equilibrium point of the game in infinite case, evolutionary stable strategy (ESS) was used here.

The entire paper is divided into five sections. Section II provides the related works. In III we formulate Stackelberg games with infinite strategy space for spam detection and Then, explain the evolutionary stable strategy to find the needed equilibrium. in section IV we describe the experimental setup and presents and discuss the experimental results. And it followed by conclusion in section V.

II. Related Works

Numerous methods have been proposed in the literature for dealing with unsolicited emails and researchers continue introducing new methods for managing the different extensive dimensions of spams. As a case in point, list-based methods such as black list, white list and grey list can be mentioned. By classifying senders into the two category of spam and legal senders, these filters try to identify spams. Although these filters are simple, they are not adequately efficient because they possess fixed rules and regulations which can be identified and eluded by spammers. In [1], methods were discussed in which they change addresses to detect spams as emails and also to detect websites which spammers use to hide their webpages. In [2], DNSBL was used for analyzing the behavior and the efficiency of the black list and the elimination power and the conditions at which black list is not used have been discussed. The results showed that combining black listing with a spam refining program can have higher efficiency.

Due to the shortcomings of the list-based methods, content-based methods which are categorized into word-based, rule-based and statistical filtering methods gained more popularity and attraction. Machine-learning methods are a kind of content-based methods. Each of the machine learning methods can have acceptable performance, the studies [3], [4], [5], [6], [7] demonstrated the positive effect of pre-processing and feature selection in machine learning methods such as Naïve Bayesian, Support Vector Machine, K-Nearest Neighbor, Artificial Neural Network and Decision Tree. Also, the combination of these methods leads to the improvement of the precision [8]. Based on the results of the studies reported in [9], [3], [8], [10], [11] and [12], it can be maintained that NB is one of the strongest available algorithms for categorizing emails which uses probabilities for detecting the class of new data.

Also, filters, it is deceived less than list-based filters. In general, each of the machine-based learning methods has its own merits and demerits. According to the findings reported in [4] and [5], the benefit of SVM method is that it can solve the problem of finite samples. However, it should be noted that the Kernel function and c parameter should be determined correctly for it. A function was proposed for kernel in [13]. The main challenge of the artificial neural networks is determining the number of nodes in the secret layer and the number of appropriate repetitions for finding weight. Nevertheless, despite having high precision, extensive calculations are one deficiency of the artificial neural network [6], [7], [14], [15] .The simplicity of implementation and the ease and speed of learning with regard to KNN have resulted in the popularity of KNN. At the same time, it should be noticed that the specification of similarity criterion and the selection of the appropriate number of neighbors (k) are the main problems of this algorithm [16]. Decision tree is a common method in data-mining which is easy to understand and evaluate. The exponential growth of the decision tree in line with problem growth is a challenge of this algorithm. Hence, NBTree and J48 were proposed to sort out this issue [17].

Inasmuch as spammers try to deceive filters by changing the content or components of emails, hence, investigating the behavior of the spammer and considering his actions will lead to the optimization of the email classifying methods. The issue of learning adversary's behavior was first proposed in [18] where a game between spam filter and adversary was proposed. However, since any changes in the players will make this method non-executable, hence, it is practically unusable. For solving this problem in [19] and [20], spam senders try to identify filter parameters by first learning the adversary's behavior and reverse engineering; next, they plan their attacks based on it. In this method, there is no equilibrium point for the adversary and spam filter [21]. Also, in [22], adversary's learning model was designed based on game theory. The rationale behind this modelling is to achieve an equilibrium point for the adversary and spam filter and it is assumed that filter and adversary have full understandings of each other's behavior. The genetic heuristic algorithm was used for solving this game in the unlimited space and achieving an equilibrium point. In [21], the relations between the adversary and filter was modelled as a turn game where there is a leader and a follower. Then, an attempt was made to solve the optimization program through evolutionary strategies. The results indicated that filtering accuracy rate has been improved in this method. In [23], the relations between spammers and user was modelled as a competitive game. Then, the strategy between them is consequently predicted. Next, the prediction is used for adjusting spam filters. In this method, it was assumed that there is a filter on the system and the user can choose whether he wants to read the received email or the spam. This game has a Nash equilibrium and the objective is to achieve an equilibrium so that the adversary's strategies can be guessed by means of this equilibrium.

III. The Proposed Method

The method introduced in this paper is based on game theory which was used to guess the adversary's action and, consequently, adopt the best strategy for the filter. As illustrated in figure 1 for the proposed method, after pre-processing and using a learning algorithm for filtering spams, the relations between adversary and filter was assumed to be of the Stackelberg game type. That is to say, the first player, namely the adversary plays the role of leader and it can impose its own strategy on the second player, i.e. filter. Hence, assuming that the follower selects the best possible decision based the leader's strategy, hence, the leader tries to adopt the most appropriate decision. Then, based on the leader's strategy, the follower reacts with respect to the payoff. In most cases, backward induction is used for finding Stackelberg equilibrium point. In the assumption of the problem, the strategy space for the two players was considered to be complex and unlimited.

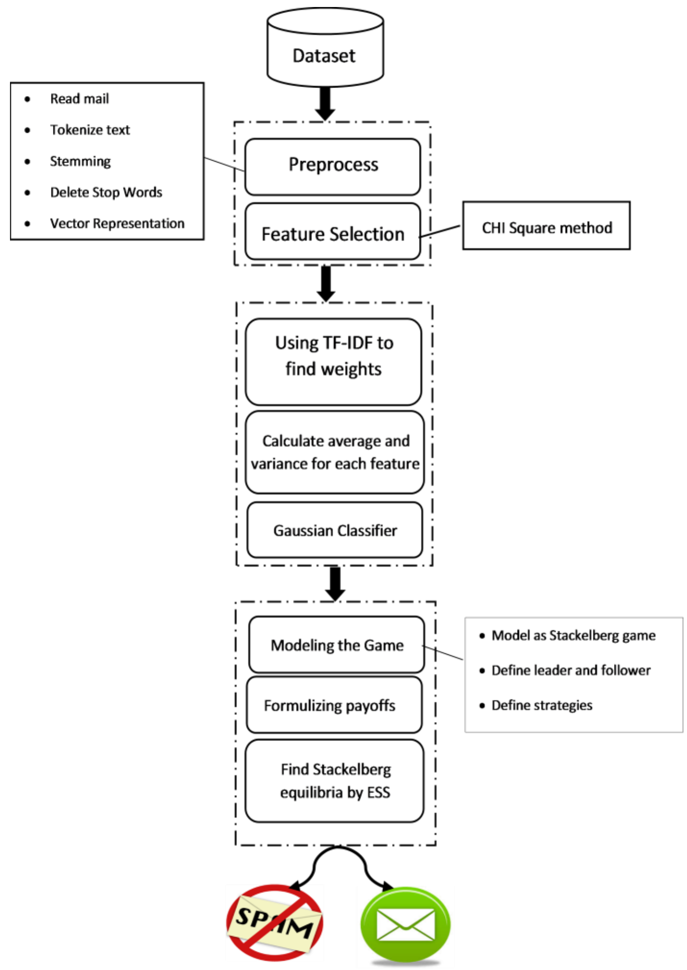

Fig. 1. Schematic View of Proposed Method

A. DataSet

Inasmuch as there was no available Farsi dataset for filtering spam, the dataset used in the study included personal emails of 4 users for approximately 8 months which were collected in 2012-2013. The dataset which was collected by the researchers included 682 legal emails and 629 spams. Tagging was used for isolating email sections. Among the collected emails from the dataset, about 80% was used for learning system and 20% was used for the testing phase.

B. Preprocessing

Email classification methods are similar to text classification methods. Figure 2 depicts the text classification. For doing the preprocessing stage for each user, at first, spam classes and legal classes should be read from the related folder and the class of each one should be specified. After reading the content of emails from each class, the available words in the email which were obtained from the body and title parts were separated token by token and the emphasis words and the stop words were eliminated. Next, the words were extracted from inside of the emails; then, the obtained words were illustrated in a vector based on their frequencies. Next, using CHI method [24] and [25], some words which could distinguish classes from one another were selected as the best words. Afterwards, by weighing words via TF-IDF method [26], the weight related to each feature was calculated; then, feature mean and variance were calculated for class which were used in the next stage.

C. Game modelling

It was assumed that data belong to a specific one-dimensional space and they are distributed normally. Spam distribution is determined by $S \sim N(\mu_s, \sigma_s)$ and legal email distribution is determined by $H \sim N(\mu_H, \sigma_H)$. İn the game, spammer plays by moving the boundary towards μ_H and also filter tries to maximize its payoff by changing the boundaryline.

The initial state of the game is illustrated in figure 3. TPs stand for spams which are truely spams but FPs are legal emails which were wrongly classified as spams. Moreover, TNs are the legal emails which are correctly classified but FNs denote wrongly classified spams. Adversary's purpose is to enhance the number of FNs. Hence, it will lead it message feature space towards the space of legal email feature (figure 4). In contrast, as the filter notices the adversary's strategy and system learning for a second time, it determines the best threshold (figure 5).

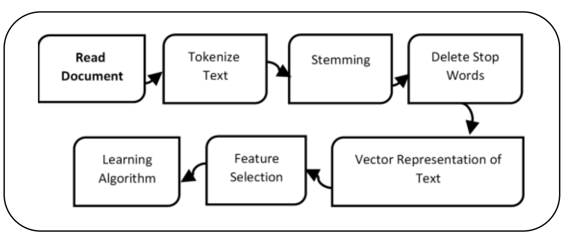

Fig. 2. Text Preprocessing

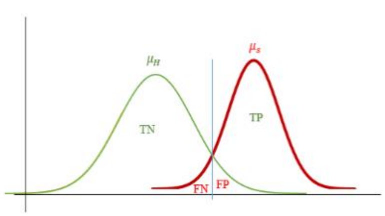

Fig. 3. Initial state of the game between spammer and filter

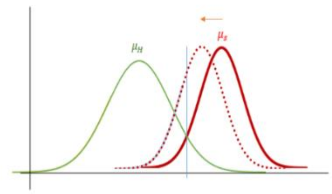

Fig. 4. adversary's strategy

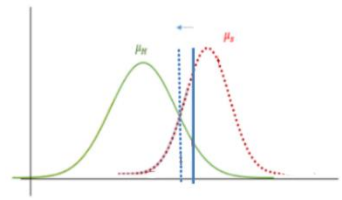

Fig. 5. filter's strategy

The ultimate goal of the game is to achive the equilibrium point. Assuming that players are aware of one another's payoff function, the purpose function of the players will be used to examine it. Then, ESS is used to calculate the equilibrium point of the game.

D. Stackelberg equilibrium point

Each player consists of a set of strategies which are labelled as U and V for the leader and the follower, respectively; also, u and v denote the feature space of them, respectively. Furthermore,each player has one differentiable payoff function which is defined as $J_i(\mathrm{U}, \mathrm{V}) \rightarrow \mathrm{R}$. U and V are bounded and convex and regarding the adversary player's movement, the strategy is defined in the following way [22]:

$$\begin{aligned} R_L &= \arg \max_{v} J_{\,L}\,(u, v) \\ R_F &= \arg \max_{u} J_{\,F}\,(u, v) \end{aligned} \tag{1}$$

Stackelberg equilibrium point is an equilibrium in which until the time the player sticks with its own selected strategy, none of the other two players have any motivations for changing their strategies [21].J^i Refers to the cost function for i player. The best response for each i player is denoted by $\mathrm{R_i}$. One solution for the Stackelberg equilibrium is produced by the following method [21]:

$$\mathbf{u}^* = \mathbf{arg} \ \max_{\mathbf{u \epsilon U}} \quad \mathbf{J^L}(\mathbf{u}, \mathbf{R_F}(\mathbf{u})) \tag{2}$$

By doing so, the follower responds whether the optimal value is:

$$\boldsymbol{v}^* = \boldsymbol{R_f}(\boldsymbol{u}^*) \tag{3}$$

One mathematical method for obtaining Stackelberg equilibrium in two-player games is to apply bi-level programming problem [27]. In this study, equation 8 can be used as the bi-level programming problem where each player tries to maximize its own payoff [22].

$$\max_{\mathbf{u}} \quad \mathbf{J^L}(\mathbf{u}, \mathbf{v}) \qquad \mathbf{s.t\; g}(\mathbf{u}, \mathbf{v}) \leq \mathbf{0} \tag{4}$$

$$\mathrm{v} \in \arg \max_{\mathrm{v}} \ \{ \mathrm{J^F}(\mathrm{u}, \mathrm{v}) \mid \mathrm{h}(\mathrm{u}, \mathrm{v}) \leq 0 \} \tag{5}$$

In equation 9, h and g variables are the limitations in U and V action spaces. Since bi-level programming problem is regarded as an NP-Hard problem, ESS was used for finding the equilibrium point.

E. Formulizing payoffs

Using probability density function in the normal space $N(x,\mu,\sigma)=\frac{1}{\sqrt{2\pi\sigma}}e^{-\frac{(x-\mu)^2}{2\sigma^2}}$, we can obtain cumulative density function$F(t,\mu,\sigma)=\int_{-\infty}^{z}N(t,\mu,\sigma)dx$. The adversary's payoff can be defined as the degree of spams which can pass through filter as legal email-the cost of transmission from one normal space to another normal space (equation 6). In case there is a dataset with several features, assuming that the features are independent, equation (7) is obtained [21].

$$\boldsymbol{J_L(u,w)} = FNR - \boldsymbol{\alpha KLD(\mu_s,\sigma_s,\mu_s-u,\sigma_s)} = \boldsymbol{F(\omega,\mu_s+u,\sigma_s)-\alpha KLD(\mu_s,\sigma_s,\mu_s+u,\sigma_s)} \quad (6)$$

$$J_L(U,W)=\frac{1}{q}\sum_{i=1}^{q}J^L(u_i,w_i) \quad (7)$$

q denotes the number of features and KLD is a notion for estimating the impact of transmitting the space of spam the size u on the initial data; indeed, it is a criterion for evaluating the degree of closeness of probabilistic models to the accurate distribution of the population. For measuring the impacts of transmission from $N(\mu_1,\sigma_1)$to $N(\mu_2,\sigma_2)$, equation (8) is used [22].

$$\boldsymbol{D_{KL}(N_1,N_2)} = \boldsymbol{\frac{1}{2}\left(log\left(\frac{det\Sigma_2}{det\Sigma_1}\right)\right)+tr(\Sigma_2^{-1}\Sigma_1) + (\mu_2-\mu_1)^T\,\Sigma_2^{-1}\,(\mu_2-\mu_1)} \quad (8)$$

Filter rewared is interpreted as the enhancement in the rate of correct acceptance and correct rejeaction [22].

$$\boldsymbol{J_F(u,w)} = TPR+TNR - \boldsymbol{\beta(\omega-\frac{\mu_s\times\sigma_H+\mu_H\times\sigma_s}{\sigma_H+\sigma_s})^2} = \boldsymbol{2F(\omega,\mu_H,\sigma_H)-2F(\omega,\mu_s-u,\sigma_s) - \beta(\omega-\frac{\mu_s\times\sigma_H+\mu_H\times\sigma_s}{\sigma_H+\sigma_s})^2} \quad (9)$$

$$J_F(U,W)=\frac{1}{q}\sum_{i=1}^{q}J^F(u_i,w_i) \quad (10)$$

α

adjusts the distance criterion on the degree of spam space transmission. İts enhancement leads to FNR reduction. In contrast, by controlling the degree of movement of w, β leads to the FPR reduction. İn case zero is selected for both parameters, $\frac{\mu_s+\mu_H}{2}$ will be considered as the threshold algorithm. Moreover, since both parameters are zero, the adversary will not pay any cost for transmission. As a result, by selecting the highest transmission value, spam space will be completely consistent with the space of legal emails. Under this condition, the degree of system error will be 50%; in fact, α can not practically be zero. As more value is regarded for α, the adversary will have to pay more cost. Consequently, a smaller value is selected for u. in case β has the value of zero, the system will not distinguish between wrong and right pass rate. However, as β increases, filter will hardly change the threshold. Consequently, a value close to the previous threshold value will be selected. This parameter can be used to distinguish between wrong and right pass rate. In other words, it can be used for weighing.

F. Evolutionary stable strategy (ESS)

In case ESS strategy is selected by all the members of a population, no other mutation strategy can overcome it. If a strategy is evolutionary and stable, hence, there will be Nash equilibrium but the requirement for the evolutionary stability of a Nash equilibrium is that it will be a strict Nash equilibrium.

TABLE I. TECHNICAL SPECIFICATIONS OF EVOLUTIONARY STABLE STRATEGY

Initial population	$u\epsilon[\mu_H,\mu_s]$ and $w\epsilon[w,\mu_H]$ K random conversion of u and w
Parents' selection	random
Fitness function	Each player maximizes his or her payoff
mutation	Gaussian mutation with zero average and l standard deviation
Termination condition	Particular number of generations

In most studies and books, ESS method has been considered for the symmetrical games. Nevertheless, in this study, there are two non-symmetrical (different) players. Player I has the strategies of i=1,2,…, m and player J has the strategies of j=1,2,……...,n. at any moment, p_i and q_j indicate the selection of i and j by the players I and J, respectively. p = $(p_1,\dots,p_m)$ and q = $(q_1,\dots,q_n)$ are the probabilistic vectors which determine population status together. The fitness of i is denoted by F(i) and the fitness of j is denoted by G(j) which depend on (p,q) at the given moment. Hence, the fitness function is defined as F(i|p,q) and G(j|p,q).

Overall schematic view of the proposed algorithm: ESS(evolutionary stable strategy)

1. Initial population is randomly created
2. Players play together and the profitability of each strategy is measured.
3. The strategies with more profitability values are reproduced in society.
4. Steps two and three are repeated until the society achieves stability.
5. Some members begin to change their own strategies (mutate).
6. Until reaching the termination condition, algorithm is repeated from step 2.

Fig. 6. schematic view of the proposed algorithm

IV. EXPERIMENS & RESULTS

In the experimental phase, after training the system by the training data (80% of samples), test data (20% of samples) is used for evaluating system. The results of experiments are given below in the form of tables and figures.

Evaluation criteria: in text classification problems, the following criteria are usually used:

$$accuracy=\frac{TP+TN}{TP+TN+FP+FN} \quad (11)$$

$$precision=\frac{TP}{TP+FP} \quad (12)$$

$$recall=\frac{TP}{TP+FN} \quad (13)$$

$$F_1 = \frac{2*(precision*recall)}{precision+recall} \quad (14)$$

A. Results of training phase

As mentioned before, game model was produced in the training phase and was executed on each component of dataset; then, using ESS which was proposed in [21] and the ESS of the equilibrium point, the results were measured. The higher the adversary payoff and the higher the filter payoff, the algorithm will be more precise and accurate. Variables of the problem were evolved in 100 generations and the best member of each generation was used. Similar to the study reported in [21], the value of α parameter in the Kullback-Leibler equation was considered to be 0.01. As illustrated in figures 7 and 8, it can be argued that ESS method is far better than ES (evolutionary Strategy).

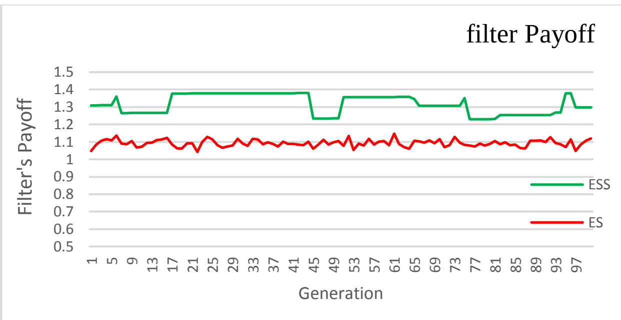

Fig. 7. average filter payoff with one feature on Evolutionary Strategy and Evolutionary Stable Strategy

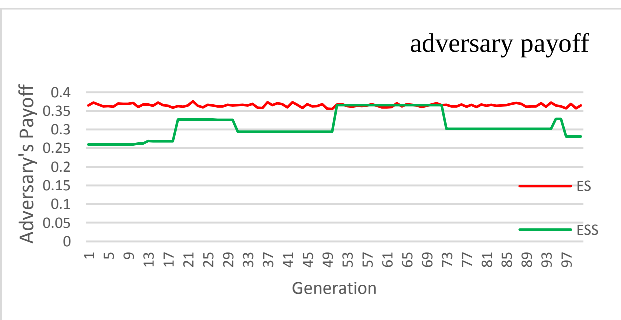

Fig. 8. Average adversary payoff with one feature on Evolutionary Strategy and Evolutionary Stable Strategy during 100 generations

For a second time, algorithms were executed separately for 100 features and average payoffs were taken into consideration. 90 samples were used for training. Payoff function is linear and the problem variables were evolved in 100 generations.in each generation, average chromosomes were given (not the best chromosomes). The payoff which is obtained for ESS is the best chromosome of the generation because, at the end of each execution, strategies are stabilized and all of them become identical. Regarding these issues, as depicted in figures 9 and 10, it can be maintained that, in most cases, ESS has better performance than ES. Furthermore, with respect to the results, it can be observed that 100 generations are not sufficient for evolution. Hence, more repetitions are need for achieving evolution. However, since there is not one equilibrium point, it can be argued that, in 100 generations, a near-optimal response can be achieved. Based on the strategy of the opposite side, payoffs in each generation can be more or less because each player not only has unlimited strategy space and acts smartly but also it is aware of the strategy of the other side. Based on the other side's strategy, it selects the most appropriate condition for itself.

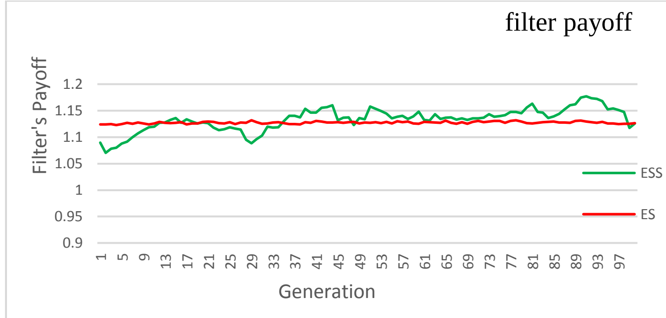

Fig. 9. Average filter profits for 100 features on Evolutionary Strategy and Evolutionary Stable Strategy in 100 generations (average chromosomes)

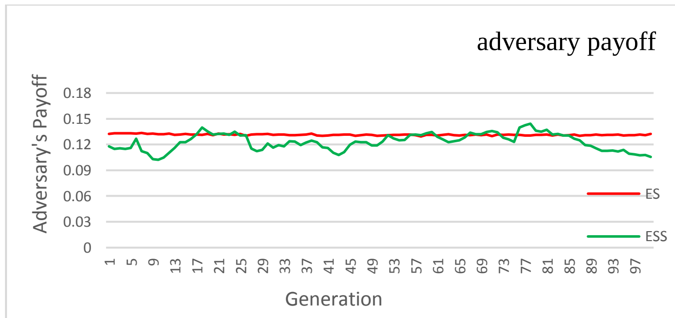

Fig. 10. average adversary's profits for 100 features on Evolutionary Strategy and Evolutionary Stable Strategy in 100 generations (average chromosomes)

B. Results of the experimental phase

In this phase, the final position of the filter and adversary at the equilibrium point were obtained for each feature by the data of the training phase. Then, these positions were used to obtain the following evaluation criteria:

- One sample is selected from each dataset of the experiment phase. It should be specified that each feature dedicates the sample to which classification.
- Class label for all the features of the sample is determined by the previous method.
- The sample class depends on the largest number of labels which is specified by the features.

The researcher and collector of the dataset has argued that 65 samples and 90 features are the best and most desirable number of samples and features for training and testing in his own research; she used the same number of samples and features in his evaluations. In a similar vein, in this study, 90 features and 65 samples were used to test the implementation methods. The average evaluation criteria were used and the equilibrium point was measured by the ES and ESS which are given in table 3.

The highest precision was desirable in the system used in this study because the higher is the precision, the lower will be the wrongly accepted rate. Indeed, it should be noted this issue is of high significance in filtering and investigating spams. The obtained results indicated that the precision of the filter for the modelling method and solving the game by ESS and ES was better than those of other methods.

TABLE II. AVERAGE EVALUATION CRITERIA FOR FINDING GAME EQUILIBRIUM POINT BY ES AND ESS ON REAL DATASET

	Before	ES	ESS
Accuracy	0.764877	0.795356	0.796081
Precision	0.887694	**0.894732**	**0.902213**
Recall	0.628447	0.693759	0.703919
F1	0.712426	0.754676	0.755538

TABLE III. RESULTS OF THREE-CLASS CLASSIFICATION FOR FARSI EMAILS BASED ON THE CRITERIA: PRECISION, RECALL AND F ON REAL DATASET

	NB	SVM	KNN
Precision	86/225	**86/425**	83/875
Recall	85/15	**85/175**	84/65
F1	**85/775**	85/075	85/6064

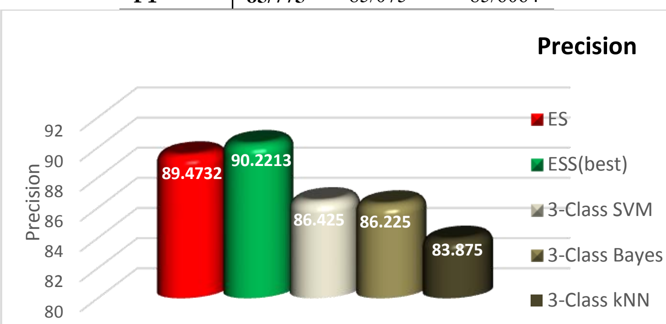

Fig. 11. Comparison of average accuracy of the results of the proposed method with those given in [9]

As showed in Figure 11 the methods of Stackelberg game and finding the equilibrium point by ES and ESS had 89.4% and 90.22% which achieved the highest precision among other methods. It should be noted that the method used in [9] which had used three-class classification on the dataset of Farsi emails had the precision value of 86.42%.

V. CONCLUSION AND DIRECTION FOR FURTHER RESEARCH

In the present study, game theory was used to investigate the relations between filter and adversary and the detection of spams by filter was considered. Regarding their payoff functions, the two players selected the best strategies. After repeating the game, they reached an equilibrium point. It should be pointed out that both players played smartly and they were interested in enhancing their own payoffs and, consequently, favored a reduction in the adversary player's payoff. The results of the experiments indicated that the evolutionary stable strategy (ESS) was able to find game equilibrium point with more precision than ES method. That is, ESS had 79.6% accuracy rate, 90.2% precision, 75.5% F criterion and 70.3% recall. In contrast, ES had 79.5% accuracy rate, 89.4% precision, 75.4% F criterion and 69.3% recall. Since speed and time are of high significance in modern life, as a direction for further research, we should focus on reducing and optimizing training time in future studies.

REFERENCES

[1] K. Bhargrava, D. Brewer and K. Li, "A Study of URL Redirection Indicating Spam," in Sixth Conferance on Email and Anti-Spam, Mountain view, California, 2009.

[2] S. Tomas and F. Radim, "Improving efficiency of e-mail communication via SPAM elimination using blacklisting," in 21st Telecommunications forum TELFOR, 2013.

[3] T. A., M. E. and K. N., "An Evaluation of Machine Learning Techniques for Enterprise Spam Filters," 2004.

[4] R. Shams and R. E. Mercer, "Classifying Spam Emails using text and readability features Data Mining (ICDM)," in IEEE 13th International Conference, 2013.

[5] W. L. a. L.-F. K. Yuxin Meng, "Enhancing Email Classification Using Data Reduction and Disagreement-based Semi-Supervised Learning," in Communication and Information Systems Security Symposium, IEEE ICC, 2014.

[6] T. Tich Phuoc, T. Pohsiang and J. Tony, "An Adjustable Combination of Linear Regression and Modified Probabilistic," in 19th International Conference on Pattern Recognition (ICPR), 2008.

[7] S. A. Seyyed Hossein and M. Saeed, "Genetic-based Feature Selection for Spam Detection, Electrical Engineering (ICEE)," in 21st Iranian Conference, 2013.

[8] M. T. Banday, "Effectiveness and Limitations of Statistical Spam Filters," in International Conference on New Trends in Statistics and Optimization, Organized by Department of Statistics, University of Kashmir, Srinagar, India, October 2008.

[9] N. Vasfi-sisi and M.-R. Feizi-Derakhshi, "Three-Class Classification of Persian Emails by Naïve Bayes Algorithm," in International Conference on Machine Learning, Electrical and Mechanical Engineering (ICMLEME'2014), Dubai, 2014.

[10] H. Wang, G. Zheng and Y. He, "The Improved Bayesian Algorithm to Spam Filtering," in Proceedings of the 4th International Conference on Computer Engineering and Networks, 2015.

[11] G. Kaur and E. N. Oberai, "Naïve Bayes Classifier with Modified Smoothing Techniques for Better Spam Classification," International Journal of Computer Science and Mobile Computing, vol. 3, no. 10, pp. 869-878, October-2014.

[12] Y. Zhang, X. Yang and Y. Liu, "Improvement and Optimization of Spam Text Filtering System," in 3nd International Conference on Computer Science and Network Technology, 2012.

[13] Y. L., Z. Z. and J. Z., "A word sequence kernels used in spam filtering," Academic Journals, vol. 6, pp. 1275-1280, 2011.

[14] P. Kumar, P.Kumareasan and S. Babu, "Accuracy Analysis of Neural Networks in removal of unsolicited e-mail," International Journal of Computer Applications, vol. 16, no. 3, Februrary 2011.

[15] S. Shaveen, C. Anish and P. L. Sunil, "Improving Spam Detection Using Neural Networks Trained by Memetic Algorithm," in Fifth International Conference on Computational Intelligence, Modelling and Simulation, 2013.

[16] P. I. Nakov and P. M. Dobrikov, "Non-Parametric Spam Filtering based on kNN and LSA," in 33th National Spring Conferance, 2004.

[17] S. Chakraborty and B. Mondal, "Spam Mail Filtering Technique using Different Decision Tree," International Journal of Computer Applications, vol. 47, no. 16, 2012.

[18] N. Dalvi, P. Domingos, Mausam, S. Sanghai and D. Verma, "Adversarial classification," in KDD '04 Proceedings of the tenth ACM SIGKDD international conference on Knowledge discovery and data mining, New York, 2004.

[19] D. Lowd and C. Meek, "Good word attacks on statistical spam filters," in Proceedings of the second conference on email and anti-spam (CEAS), Redmond, WA, 2005/7.

[20] D. Lowd and C. Meek, "Adversarial Learning," in Proceedings of the eleventh ACM SIGKDD international conference on Knowledge discovery in data mining, New York, 2005.

[21] N. Sadigh, S. Hashemi and A. Hamzeh, "SPAM DETECTION BY STACKELBERG GAME," Advanced Computing: An International Journal (ACIJ), vol. 2, no. 2, 2011.

[22] W. Liu and S. Chawla, "A Game Theoretical Model for Adversarial Learning," in Data Mining Workshops, 2009. ICDMW '09. IEEE International Conference, Miami, 2009.

[23] Androutsopoulos, E. F. Magirou and D. K. Vassilakis, "A Game Theoretic Model of Spam E-Mailing," in 2nd Conference on Email and Anti-Spam, Athens, Greece, 2005.

[24] Y. Yang and J. Pedersen, "A comparative study on feature selection in text categorization," 1997 .

[25] M. Bitarafan and S. Jalili, "increment text classification performance based improve feature selection methods," Journal of the Technical University, vol. 40, no. 3, pp. 313-328, 2006.

[26] Q. Ren, "Feature-Fusion Framework for Spam Filtering Based on SVM," in In Proceedings of the 7th Annual Collaboration, Electronic messaging, Anti-Abuse and Spam Conference, Washington, US, 2010.

[27] L. N. Vicente and P. H. Calamai, "Bilevel and multilevel programming: A bibliography review," Journal of Global Optimization , vol. 5, no. 3, pp. 291-306 , 1994.

SecFHIR: A Security Specification Model for Fast Healthcare Interoperability Resources

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***Abstract*—Patients taking medical treatment in distinct healthcare institutions have their information deeply fragmented between very different locations. All this information --- probably with different formats --- may be used or exchanged to deliver professional healthcare services. As the exchange of information/ interoperability is a key requirement for the success of healthcare process, various predefined e-health standards have been developed. Such standards are designed to facilitate information interoperability in common formats. Fast Healthcare Interoperability Resources (FHIR) is a newly open healthcare data standard that aims to providing electronic healthcare interoperability. FHIR was coined in 2014 to address limitations caused by the ad-hoc implementation and the distributed nature of modern medical care information systems. Patient's data or resources are structured and standard in FHIR through a highly readable format such as XML or JSON. However, despite the unique features of FHIR, it is not a security protocol, nor does it provide any security-related functionality. In this paper, we propose a security specification model (SecFHIR) to support the development of intuitive policy schemes that are mapping directly to the healthcare environment. The formal semantics for SecFHIR are based on the well-established typing and the independent platform properties of XML. Specifically, patients' data are modeled in FHIR using XML documents. In our model, we assume that these XML resources are defined by a set of schemes. Since XML Schema is a well-formed XML document, the permission specification can be easily integrated to the schema itself, then the specified permissions are applied to instance objects without any change. In other words, our security model (SecFHIR) defines permissions on XML schemes level, which implicitly specify the permissions on XML resources. Using these schemes, SecFHIR can combine them to support complex constraints over XML resources. This will result in reusable permissions, which efficiently simplify the security administration and achieve fine-grained access control. We also discuss the core elements of the proposed model, as well as the integration with the FHIR framework.**

Keywords—Healthcare; FHIR; Interoperability; Privacy preserving; Standards; XML schema

I. Introduction

Vast amount of information on health is created in the process of treatment in different medical centers such as hospitals, clinics, or other institutions. As a result, the information about patients becomes scattered over a large number of distinct health information systems [1]. To provide appropriate treatment, this information may need to be accessed and exchanged towards the successful execution of medical process. However, the variety of involved providers, as well as the diversity of health data, end up not being used due to the difficulties faced in exchanging and integrating issues. In fact, despite the recent research in the domain of information systems, it is still not completely settled out the exchanging and integrating challenges. This leads to inefficient treatment as the individuals' information may need to be accessed and processed at the right time and place [2].

The dis-connect in systems is due to two important reasons. First, the technological challenges for integrating heterogeneous legacy systems/information, which are almost impossible to directly include into any reasonable interoperable work-flow. Second, the lack of enforceable security policies for data interoperability and exchange as many healthcare applications operate in isolated mode that do not share information in an efficient manner. The solution for the former problem can be found in the frameworks that regulate how information is structuring and exchanging, while providing a security specification model can solve the latter problem.

We note that existing approaches have been proposed to achieve interchanging information (interoperability). Interoperability is widely acknowledged as a key requirement for the success of healthcare information systems. For example, the interoperability has a considerable benefits to national economies throughout the world, it has been estimated at USD\$77.8B [3] in the USA alone. Therefore, organizations proposed several approaches to provide interoperability. Health Level Seven (HL7) organization, as an example, developed a comprehensive framework and related standards for exchanging, integrating, and sharing healthcare data since 1987 to improve patient care [2, 4]. Recently, Fast Healthcare Interoperability Resources (FHIR) is introduced as a next generation standard to address fundamental limitations in HL7, and provide an implementable framework, supported by the prior experience, to apply best practices and avoid some of the pitfalls of previous work [5, 6].

FHIR attains interoperability in part by the use of consistent standards that define the syntactic and semantic meaning of information. Of course, using consistent standards reduce time, effort, and costs of health technology development projects. In practice, FHIR represents granular clinical concepts as a set of resources that may be addressed separately or in aggregating mode such as Patient, and Document. Its build upon the HL7-defined set of ``resources" aiming to support more modern approaches and be more developer-friendly for information sharing, which includes documents, messages, services and RESTful interfaces. Some of these infrastructure resources define the standard itself --- i.e. what coding are used with them, what are resources' characteristics, etc. This set of resources is referred to as the "Conformance resources" [7,8,9].

That being said, while FHIR provides the most interesting standard since the original HL7, for exchanging health data in highly readable format such as XML, it does not define any kind of security related functionality [5]. In other words, the biggest concern is not just exchanging the patients' information but also preserve patients' privacy. The provided interoperability feature requires a proper level of awareness to provide the right security countermeasures. The security and privacy issues that arise within this context can then be handled with the appropriate policy specification that identifies and authenticates users in order to preserve the patients' privacy. For example, in a healthcare heterogeneous environment, an XML document generated according FHIR standards can consist of information about patients. In case of accessing this document by internal or external user, her access permissions should be validated according to security policies. The final decision which determines whither user can read or not is the result of the overall authorization constraints.

To control all accesses to XML instances in such environment without doing major changes to FHIR structuring, we propose a policy specification model (SecFHIR) that is based on XML Schema. SecFHIR relies on the concepts of XML Schema that supports complex constraints over XML elements in an XML instances. These instances can then be combined together to create more expressive policies. A primary objective of this approach is to allow policy designers to identify security/privacy constructs taking into account the requirements of healthcare environments such as the highly dynamic nature and the exceptional circumstances where privacy policy is override in emergencies cases. To support the evaluation of the proposed approach, we provide a prototype implementation developed specifically for this environment. The framework consists of three main components. The User Interface Tool allows end users to design policies either by using an XPath or the XQuery to be a XML query language with SQL-like syntax that directly interacts with the information repository. The Policy Repository, in turn, stores the policies generated by the interface tool. Finally, the Policy Manager retrieves policies from the repository and delivers them to the access control module for enforcement.

The remainder of the paper is organized as follows. An overview of related work is presented in Section II. Section III discusses the terminology relevant to the Fast Health Interoperable Resources and FHIR Information Modeling. The security specification model is then presented in detail in Section IV. The integration to FHIR framework discussed in Section V. Final conclusions and the future work are offered in Section VI.

II. Related Work

The need for developing standards for the exchanging of electronic health information has long been identified in the literature. In 1987, the Health Level Seven International (HL7) has founded as a non-profit organization dedicated to developing a comprehensive framework for the exchange and retrieval of electronic health information [2]. Recently, in 2014, the Fast Healthcare Interoperability Resources (FHIR) is introduced as a next generation standard to address fundamental limitations in HL7, where the patient's information or resources are structured and standard through a highly readable format such as XML or JSON [5]. However, a primary limitation of this approach is that it lacks for security countermeasures.

Because FHIR defines patient's resources as XML documents, some related works concerning XML security can be considered. Ponder2 as an example, which is an XML-based language that specifies security and management policies in a subject-action-target (SAT) format [10]. SecPAL credentials 30], on the other hand, are expressed using predicates defined by logical clauses, in the style of constraint logic programming. We note, however, that while these approaches are efficient when used on large-scale networks and distributed systems, they are not well-suited to healthcare information as they are often fragmented.

Creating secured views have also been considered, authors in [11] generated views for the required XML document using XSLT transformation technology. Typically, alternate views are defined for each distinct user or user group depending on their privileges. The end result is often the generation of a large number of such views, all of which must be maintained manually by the administrator. Clearly, this approach does not scale terribly well, and would be impractical in complex healthcare environment.

The encryption and key management technology have also used in this context. Authors of [12] provided a solution using encryption technique to secure delivery of XML documents, while authors of [27] encrypted their data before uploading them to cloud servers. This enables patients to create, modify, manage and control data in a centralized place from anywhere and at any time, as well as to share their data with wide range of users. However, for a well-designed encryption technique time-consuming brute force method and large computational resources are required to decrypt the data.

The RBAC model has been utilized to provide XML security. For example [13] defined their own language to describe roles and permissions, which are kept in RBAC model for XML document stores. In fact, a number of researchers have looked at similar techniques, for example in [14], the RBAC model is extended to provide an access control in Dynamic XML-based Web-Services. Authors presented an XML-based RBAC (XRBAC) policy specification framework for enforcing access control in dynamic XML-based Web services. The DTDs are also used to represent authorizations such as [15], which used XML format authorization based on DTD, and embedded this with X.509 attribute certificate.

Ultimately, from industry, eXtensible Access Control Markup Language (XACML) [16], initially defined by OASIS (Organization for the Advancement of Structured Information Standards), is proposed as a declarative access control policy language that expresses policies in an XML format. SAML on the other hand, defines the sources of the security statements in XML. The XML statements are then used in the processes of authentication and authorization. Still other works investigate the integration of security assertion with client side code, with protection provided by analyzing user's requests [17]. Such XML-based languages are particularly suitable to convey requirements related to authorization and privacy for web-based systems [28]. However, it can be more difficult to adapt them to other environments (i.e., FHIR). Moreover, policies expressed directly in XML are verbose and hard to read and write [29].

III. PRELIMINARIES

As healthcare data is increasingly becoming digitized and widespread over different places. The data must be interoperable (structured and standardized) before sharing or processing by doctors. In fact, numerous health standards have been developed to support interoperability such as Fast Health Interoperable Resources (FHIR). FHIR is the recently proposed standard from HL7 organization that enables exchanging health data in highly readable XML, RDF, and JSON format [5]. It supports a user friendly implementation, built-in clinical terminologies, and is based on widely-used web standards like HTTP. In this section FHIR is briefly described, from a technical, standard and developer perspective.

A. Fast Health Interoperable Resources

The basic building block in FHIR is a Resource. All exchangeable content is defined as a resource or entity, which has a known identity by which it can address itself as one of the resource types. Example resources include: Patient, Device, and Document. At the present time there are 32 resources defined with many more under consideration. Resources all share the following set of characteristics:

- A common way to define and represent them. In the regards, a set of data types are used to building and defining common reusable patterns of elements. In fact, there are two main categories of data types: simple and complex types. The simple types are those that define single elements (e.g., string, integer, url, date, ect.). The complex types, on the other hand are re-usable clusters of elements. These types are represented as XML elements with parent-child relationship and all the presented elements are defined by their names and types. Any of the XML elements may have an id attribute. Fig. 1 illustrates a simple example for patient resource in XML format taken from [18], where the “patient_example” element includes several sub-elements. Each sub-element is a simple type or complex type (e.g., table).

```xml
<Patient xmlns="http://hl7.org/fhir">
  <id value="example"/>
  <text><status value="generated"/>
   <div xmlns="http://www.w3.org/1999/xhtml">
<!-- use FHIR code system to present patient information -->
      <table><tbody>
         <tr> <td>Name</td> <td>Peter James</td> </tr>
         <tr> <td>Address</td> <td>534 Erewhon, London, UK,
                                   139</td> </tr>
         <tr> <td>Contacts</td> <td>Home:(01)55556473</td></tr>
         <tr> <td>Id</td> <td>MRN:135(Acme Healthcare)</td></tr>
        </tbody></table>
    </div>
  </text>
<!--    use FHIR code system for male / female    -->
  <gender value="male"/> <birthDate value="1974-12-25">
    <extension url="http://hl7.org/fhir/StructureDefinition/
                    patient-birthTime">
      <valueDateTime value="1974-12-25T14:35:45-05:00"/>
    </extension> </birthDate>
  <deceasedBoolean value="false"/>

<!--    MRN assigned by ACME healthcare on 6-May 2014    -->
  <identifier>
    <use value="usual"/>
     <type><coding><system value="http://hl7.org/fhir/v2/0203"/>
      <code value="MR"/>  </coding>  </type>
      <system value="urn:oid:1.2.36.146.595.217.0.1"/>
      <value value="12345"/>
      <period>  <start value="2041-05-06"/>  </period>
      <assigner> <display value="Acme Healthcare"/>  </assigner>
  </identifier>
  <active value="true"/>
<!--    Relationship contacts    -->
<contact>
    <relationship>  <coding>
        <system value="http://hl7.org/fhir/patient-contact-
                       relationship"/>
        <code value="partner"/> </coding>
    </relationship>
      <name> <family value="du">
      <extension url="http://hl7.org/fhir/StructureDefinition/
                      iso21090-EN-qualifier"></extension>
      </family> <family value="Marché"/>
                <given value="Bénédicte"/> </name>
      <telecom> <system value="phone"/>
              <value value="+1 (237) 998327"/> </telecom>
      <gender value="female"/>
      <period>  <start value="2012"/>  </period>
  </contact>
  <managingOrganization> <reference value="Organization/1"/>
  </managingOrganization>
<!-- ……………… -->
</Patient>
```

Fig. 1. A patient resource in XML format

- A common set of metadata that facilitate the technical and design context for the resources. We note that, the metadata items are optional, however some of them may be required in some implementations.
- A human readable part that contains a brief description of the resource. This part is used to represent the content of the resource to a user. It provides all the information needed for a user to understand the provided clinical and business information.

B. FHIR Information Modeling

FHIR aims to present the common patients' use cases. With FHIR, the patients' information are often modeled based on the composition approach. It structures the defined information contents by combining a set of resources together through their references. This ends with set of information that can be shared by the majority of the healthcare systems. Definitely, a single resource can be used by itself for particular use cases, however in most cases resources are combined and tailored to meet common use cases with specific requirements.

IV. The Security Specification Model

As mentioned in the previous section, patient's data/resources are modeled in FHIR using XML documents. In our model, we assume that these XML resources are defined by a set of schemes. Since XML Schema is a well-formed XML document, the permission specification can be easily integrated to the schema itself, then the specified permissions are applied to instance objects without any change. In other words, our security model (SecFHIR) defines permissions on schema objects, which implicitly specify the permissions on XML resources. Using these schemes SecFHIR can combine them to support complex constraints over XML resources.

That is, a FHIR resource may be generated with varying security requirements. The user, on the other side, may have a permission to access only particular parts of such instance. So users permissions can be defined using XML Schema for the corresponding FHIR resource. After that, the permissions are transported to all XML instances specified by this schema, then it will be transparently and consistently propagated to all relevant resources specified by this specific schema before sharing it with different users. Schemes elements can be further combined together to create more expressive policies. At the same time, because of the rich relationships between schema elements or between schemes themselves the generated complex permissions can be reused. Based on these unique features, SecFHIR would express efficient permissions that can in turn simplify the security administration.

A. Proposed Architecture

In fact, the SecFHIR architecture consists of four major components: Policies Repository, Security Schemes, XML Parser, and Security Specification Engine. Figure 2 provides an illustration of the architecture itself. In the following subsections, we discuss these components and provide a brief description of their Functionalities.

a) Policies Repository: In SecFHIR, administrators are responsible for defining security policies. The defined policies consists of a series of conditions (restrictions and/or permissions) identified by users credentials. These policies are stored in the policies repository and used by the Security Engine to generate Security Schemes for the requested XML resources. Policies are stored as a set of tables (users, permissions, and data elements) in the repository that collectively represent the security meta data. Ultimately, administrators interact with the policy repository using front-end tools that is typically a graphical, interactive interface. The important of the GUI is to hide the unnecessary details and facilitate the using of resources elements to be protected in a simple way.

b) Security Schemes: The second and more significant component is the Security Schemes. Security schemes are created in SecFHIR to provide templates, or blueprints to define the security permissions for FHIR resources. At the present time there are 32 resources defined in FHIR include: Patient, Device, Document, etc. So, an equivalent number of security schemes have been created, each of which defines the permissions and access types for each resource.

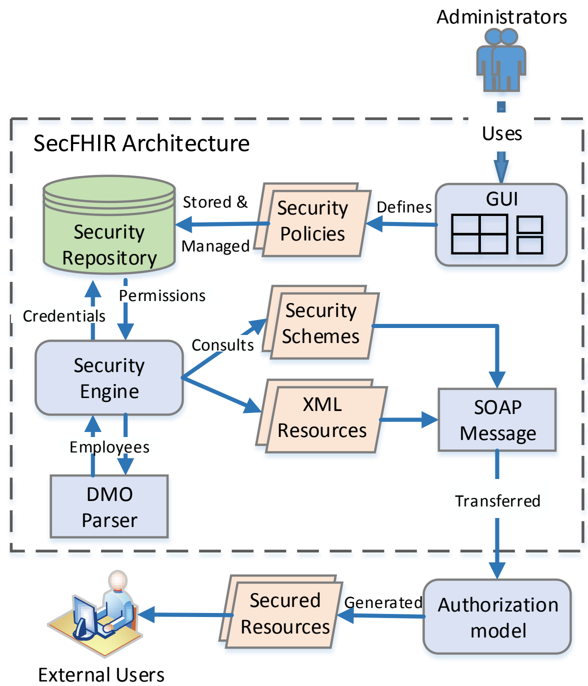

Fig. 2. The SecFHIR Architecture

For example, the core Schema in SecFHIR is the Patient schema where it is used to set the access constraints on patient's resource. Figure 3 illustrates the corresponding security schema for the XML instance shown in Figure 1. Due to the space limitation, we just provide the patient's schema, however the same principle can be applied to the remained resources.

The schema begins with the XML declaration followed by the root element. All elements may be properly nested and each element must be closed. In this schema, each component is followed by one or more < permission > tags. For example: Because XML Schema is XML like document, it can be validated and used after parsing it just like normal XML instance. In addition, the sender describes the data as the receiver will understand. Based on these features, languages like XPath and XQuery can be used to make data contained in the instance available to other applications.

c) Security Specification Engine: The Security Specification Engine is a bidirectional component. As mentioned previously, while security policies are defined and stored in the policies repository, the engine in turn, contacts the repository and retrieves the applicable policies, which are then integrated to the schema that defines the FHIR resource to be secured. Protecting FHIR resource is based on the three common access types: Read, Update and Delete.

1) Read: the most frequent operation by external users such as hospitals or healthcare centers users. A user in such institute is authorized to read the patient's info upon the permissions given to his/her roles.

```
<xs:schema attributeFormDefault="unqualified"
elementFormDefault="qualified" targetNamespace="http://
www.w3.org/1999/xhtml" xmlns:xs="http://www.w3.org/2001/
XMLSchema">
 <xs:element name="div">
  <xs:complexType>
   <xs:sequence>
    <xs:element name="table">
     <xs:annotation>
        <xs:documentation> use FHIR code system to
                                    present patient information
        </xs:documentation>
     </xs:annotation>
    <xs:complexType>
     <xs:sequence>
      <xs:element name="tbody">
        <xs:complexType>
          <xs:sequence>
            <xs:element name="tr" maxOccurs="unbounded"
                                     minOccurs="0">
            <xs:permission>
                <xs:PermissionType = "read",
                                     value = "True"/>
                <xs:PermissionType = "update",
                                     value = "True"/>
                <xs:PermissionType = "delete",
                                     value = "False"/>
                </xs:permission>
        <xs:complexType>
          <xs:sequence>
            <xs:element type="xs:string"
                          name="td" maxOccurs="unbounded"
                          minOccurs="0"/>
          </xs:sequence>
        </xs:complexType>
            </xs:element>
       </xs:sequence>
      </xs:complexType>
     </xs:element>
    </xs:sequence>
    </xs:complexType>
   </xs:element>
  </xs:sequence>
  </xs:complexType>
 </xs:element>
</xs:schema>
```

Fig. 3. The SecFHIR Architecture

2) Update: is used to modify the content of a resource. The updating permission value should be set by the resource's creator on the targeted XML schema before sharing its resource.

3) Delete: this type is used to remove a resource or some elements, including the elements and contents. Also the deleting permission value should be set by the resource's creator before sharing the XML resource.

For example, refereeing to the Fig. 3 deleting the patient's information is restricted because the delete permission value is set to False, while it is authorized to read or update the information.

a) XML Parser: To properly validate and utilize the FHIR resource, it must be first parsed and decomposed into its basic elements. In fact, the DOM parser utility [19, 20] is utilized by the Security Specification Engine to produce a DOM tree that represents the raw contents for both the schema and resource. Here, the parser first verifies that the resource has valid syntax corresponding to the provided schema, and then builds the parse tree. After that the security engine is set the values for the three access types: Read, Update and Delete according to the permissions stored in the security repository.

b) Authorization Module: While the proposed model provides a security mechanism for securing the patient's information defined by FHIR, it is important to note that without an appropriate user-side authorization module to permit or deny the user access, based on the user's privileges, the process of securing patient's information is not possible. Many authorization modules have been proposed in the literature such as [21, 22, 23, 24]. For example, the authors in [24] provided an authorization model based on RBAC and XML Schema. The model can be integrated and used by user-side machines to authenticate and authorize FHIR resources accessing. At this point, one can assume that such module exists, however in the future work, we aim to design a module which satisfies the required security measures for FHIR resources.

V. INTEGRATION TO FHIR FRAMEWORK

FHIR resources can be exchanged between internal and external users. While internal users can use any proper application to use the available local information, external users have to exchange patients resources over the network. This is done by using Hypertext Transfer Protocol (HTTP), which is the best way to communicate between applications because it is supported by all Internet browsers and servers, and SOAP (Simple Object Access Protocol) message [25], which is a messaging protocol used to encapsulate data as messages and exchange them via HTTP [26].

That is, a SOAP message is an ordinary XML document contains a differentiate element that identifies the resource, a header and body elements, which contain the requested information. SecFHIR exploits SOAP messaging for sending security schemes to different users. These messages were designed so that they can be tunneled over HTTP. This would and did help in its rapid adoption. Because the infrastructure of HTTP is already in-place, users would not have to spend extra money for another kind of implementation. Instead they can expose and access web services using technology already deployed.

In addition, the integration allows to easily transferring the healthcare information in secured mode, which provides a way to communicate between different applications with different technologies running on different operating systems. The success of this integration demonstrates that the general principles behind our model are broadly applicable to any standards FHIR resource, regardless to the content of the resource.

VI. Conclusion and Future Work

The big revolution in healthcare is supported by an increasing number of modern technologies such as medical devices that help in collecting or sensing continuously patients' information. Providing efficient healthcare is highly dependent on the availability of the collected information. However, to accomplish the aforementioned goal, the data should be interoperable (able to exchange) between healthcare providers. The biggest concern is not just exchanging the patients' information but also preserve patients' privacy. Specifically, many standards have been proposed to accomplish interoperability principle such as FHIR, which is comprehensive standards for exchanging and sharing healthcare information. That is being said, FHIR does not provide any type of security nor a security protocol for transferring information. Therefore, in this paper we present a security specification model that defines security policies on the level of XML schemes. These policies are implicitly mapping to the FHIR resources and can then be combined together to support complex constraints over resources. This will result in reusable policies, which efficiently simplify the security administration and achieve fine-grained access control. In the future work, we aim to design an Authorization module that can be plugged at client side, which satisfies the required security measures for FHIR resources.

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References

[1] Rostad, Lillian. Access control in healthcare information systems. Diss. Norwegian University of Science and Technology, 2008.

[2] Benson, Tim. Principles of health interoperability HL7 and SNOMED. Springer Science \& Business Media, 2012.

[3] T. M. Alenazi and A. A. Alhamed, "A Middleware to Support HL7 Standards for the Integration between Healthcare Applications," Healthcare Informatics (ICHI), 2015 International Conference on, Dallas, TX, 2015, pp. 509-512.

[4] N. Beredimas, V. Kilintzis, I. Chouvarda and N. Maglaveras, "A reusable ontology for primitive and complex HL7 FHIR data types," 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Milan, 2015, pp. 2547-2550.

[5] Franz, Barbara, Andreas Schuler, and O. Kraus. "Applying FHIR in an Integrated Health Monitoring System." EJBI 11.2 (2015).

[6] U. Pervez, O. Hasan, K. Latif, S. Tahar, A. Gawanmeh and M. S. Hamdi, "Formal reliability analysis of a typical FHIR standard based e-Health system using PRISM," e-Health Networking, Applications and Services (Healthcom), 2014 IEEE 16th International Conference on, Natal, 2014, pp. 43-48.

[7] D. Bender and K. Sartipi, "HL7 FHIR: An Agile and RESTful approach to healthcare information exchange," Proceedings of the 26th IEEE International Symposium on Computer-Based Medical Systems, Porto, 2013, pp. 326-331.

[8] E. Osorio, L. Ferreira, R. Abreu and F. Sousa, "Interoperability in Ambient Assisted Living using OpenEHR," e-Health Networking, Applications \& Services (Healthcom), 2013 IEEE 15th International Conference on, Lisbon, 2013, pp. 394-398.

[9] G. C. Lamprinakos et al., "Using FHIR to develop a healthcare mobile application," Wireless Mobile Communication and Healthcare (Mobihealth), 2014 EAI 4th International Conference on, Athens, 2014, pp. 132-135.

[10] Twidle, K., Dulay, N., Lupu, E., Sloman, M.: Ponder2: A Policy System for Autonomous Pervasive Environments. In: IEEE Workshop on Policies for Distributed Systems and Networks, pp. 330-335. IEEE Computer Society, Washington (2009).

[11] A.Gabillon, E.Bruno, Regulating Access to XML Documents, 15th IFIP WG 11.3 Working Conference on Database Security, 2001.

[12] E.Bertino, B.Carminati and E.Ferrari, A Temporal Key Management Scheme for Secure Broadcasting of XML Documents, In Proc. 9th ACM Computer and Communications Security Conference, 2002.

[13] M.Hitchens, and V.Varadharajan, RBAC for XML Document Stores, International conference on Information and Communications security, 2001.

[14] R. Bhatti, J. B. D. Joshi, E. Bertino, and A. Ghafoor, “Access Control in Dynamic XML-based Web-Services with X-RBAC,” 2002.

[15] D.W.Chadwick, O.Otenko, The PERMIS X.509 Role Based Privilege Management Infrastructure, In Proc. of ACM Symposium on Access Control Models and Technologies, 2002.

[16] OASIS. eXtensible Access Control Markup Language (XACML) Version 3.0, Jan 2013. https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=xacml.

[17] Wang, Hongbing, et al. "Web services: problems and future directions." Web Semantics: Science, Services and Agents on the World Wide Web 1.3 (2004): 309-320.

[18] FHIR. https://www.hl7.org/fhir/

[19] S. Kabisch, D. Peintner, J. Heuer and H. Kosch, "Optimized XML-based Web service generation for service communication in restricted embedded environments," Emerging Technologies \& Factory Automation (ETFA), 2011 IEEE 16th Conference on, Toulouse, 2011, pp. 1-8.

[20] Wang, Fangju, Jing Li, and Hooman Homayounfar. "A space efficient XML DOM parser." Data \& Knowledge Engineering 60.1 (2007): 185-207.

[21] Gajanayake, Randike, et al. "Accountable-eHealth systems: The next step forward for privacy." Electronic Journal of Health Informatics 8.2 (2013): 11.

[22] Al-Hamdani, Wasim A. "Cryptography based access control in healthcare web systems." 2010 Information Security Curriculum Development Conference. ACM, 2010.

[23] Leyla, Nazia, and Wendy MacCaull. "A Personalized Access Control Framework for Workflow-Based Health Care Information." Business Process Management Workshops. Springer Berlin Heidelberg, 2011.

[24] Zhang, Xinwen, Jaehong Park, and Ravi Sandhu. "Schema based XML security: RBAC approach." Data and Applications Security XVII. Springer US, 2004. 330-343.

[25] Box, Don, David Ehnebuske, Gopal Kakivaya, Andrew Layman, Noah Mendelsohn, Henrik Frystyk Nielsen, Satish Thatte, and Dave Winer. "Simple object access protocol (SOAP) 1.1." (2000).

[26] Fielding, R., Gettys, J., Mogul, J., Frystyk, H., Masinter, L., Leach, P., & Berners-Lee, T. (1999). Hypertext transfer protocol--HTTP/1.1. Chicago.

[27] Li, Ming, Yu, Shucheng, Ren, Kui, and Lou, Wenjing. “Securing Personal Health Records in Cloud Computing: Patient-Centric and Fine-Grained Data Access Control in Multi-owner Settings". Security and Privacy in Communication Networks: 6th Iternational ICST Conference, SecureComm 2010, Singapore, September 7-9, 2010. 89-106.

[28] WS-Policy.Web services policy framework (WS-Policy) Version 1.5, Nov 2010. http://www.ibm.com/developerworks/library/j-jws18/.

[29] Moritz Y. Becker, C´edric Fournet, and Andrew D. Gordon. Secpal: “Design and semantics of a decentralized authorization language”. Journal of Computer Security,18(4):619–665, December 2010.

[30] Becker, Moritz Y., Cédric Fournet, and Andrew D. Gordon. "SecPAL: Design and semantics of a decentralized authorization language." Journal of Computer Security 18.4 (2010): 619-665.

A Comparative Study of the Iterative Numerical Methods Used in Mine Ventilation Networks

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***Abstract*—Ventilation is one of the key safety tasks in underground mines. Determination of the airflow through mine openings and ducts is complex and often requires the application of numerical analysis. The governing equations used in the computation of mine ventilation are discussed in matrix forms. The aim of this paper is to compare the most frequently used numerical analysis methods, which includes Newton-Raphson and the Linear Theory. It is the challenge of this study to investigate the influence of the initial flow rates and the fans in the network. A simulated mine ventilation network is represented in order to examine the two numerical methods. The numerical results acquired from Newton-Raphson method exhibited faster rate of convergence in comparison to those of the Linear Theory method. The mine ventilation networks are less expanded, therefore, the Newton-Raphson method converges faster. On the other hand, when using computational tools and software the advantage of faster convergence becomes less important, and therefore the Linear Theory method will be more preferred.**

Keywords—mine ventilation; network analysis; Newton-Raphson method; linear theory

I. Introduction

Mine networks often comprise a number of loops and nodes connecting all branches. The airflow and air pressure distribution in mine openings and ducts can be worked out through solving the governing equations based on conservation Theory. The objective of the mine ventilation network analysis is twofold: a) the airflows and pressure distribution around the network are determined; b) the energy losses associated with all branches including those with fans and regulating doors are calculated. The laws of mass and energy conservation are used for the achievement of these objectives. The earliest numerical method, which is primarily used in water distribution network design, is that of Hardy-Cross method [1]. This method has also been used for mine ventilation network analysis [2]. The method was further developed to Newton-Raphson method to speed up the rate of convergence. In order to satisfy continuity, some initial values may be given to the airflows. The accuracy of these estimates will affect the speed of convergence. A new method was proposed by civil engineering practitioners in designing hydraulic distribution networks [3]. It is called the Linear Theory method and also relies on approximate evaluation techniques, which include functional approximation. The method was further extended by adding pumps and reservoir to the network [4], and later applied to mine ventilation networks by Bhamidipati and Procarione [5].

The governing equations may be combined and shown in the forms of matrixes. Kolarczyk [6] discussed on the application of matrix analysis methods in determining the changes due to the resistances and air flows of branches. The operations research methods were used in analysis and design of mine ventilation systems [7]. A simulation and optimization software for mine ventilation system of underground mines was programmed [8]. The use of 3D simulation system in mine ventilation management was also reported [9]. In this paper, first the key equations used for the ventilation networks analysis in the matrix forms will be represented. Then, the two approximate evaluation techniques, the Newton-Raphson and the Linear Theory methods, will be compared. In order to disclose some of the most significant features of the two methods, an example of a simulated mine ventilation network problem will be solved to demonstrate the applicability of the iterative numerical methods used. It will aim at demonstrating the difference between the approximation methods, the associated convergence properties in particular. The matrix form problem solving approach will be useful for the development of mine ventilation network algorithms [8, 9]. The nature of oscillations in successive estimates and the way each method reaches the converged solution will be examined and discussed. Attempts will be made to show which method works more efficiently for mine ventilation networks.

II. Mine Ventilation Networks

Mine ventilation networks generally consist of a number of loops, where each loop has a number of branches. A simple form of a mine ventilation network is shown in Figure 1.

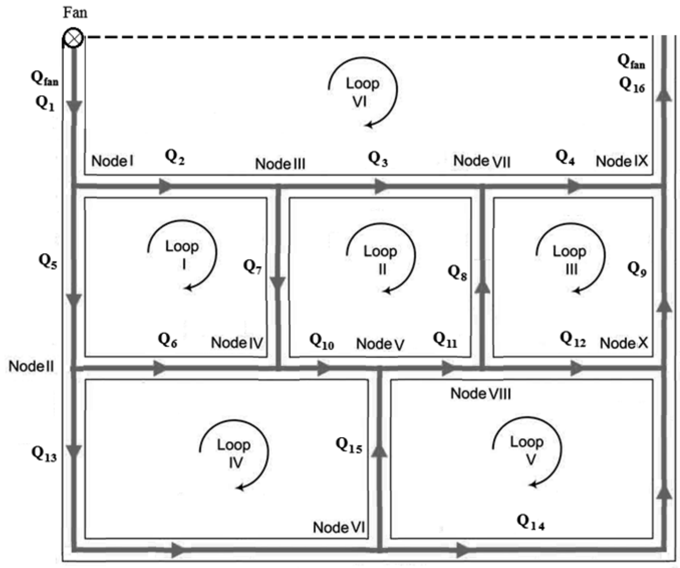

Fig. 1. An example of a simulated mine ventilation network

The branches join at nodes. Each branch represents one of the mine openings that may intersect with other openings at two ends. The network includes 5 actual loops as well as a virtual loop. It also includes 16 branches and 10 nodes. There will be lack of information about the air flows in all branches and the pressure drops concerned. Thus, the aim is to initially work out the airflows using the governing equations and taking into account the characteristics of the network. The matrix form approach will provide useful data, which then could be used in mine ventilation network algorithm and system developments [9].

Equations 1 and 2 are the governing equations used for the analysis of the ventilation networks. The first equation is satisfied for each branch to introduce the associated pressure drop, while the second equation is satisfied for each node according to the continuity law. In eq. 2, *j* represents the total number of nodes while $(j-1)$ is the number of independent nodes. Other parameters are *n*: the number of branches, R_i: the resistance, Q_i: the airflow and ΔP_i: the pressure drop due to the airflow in branches [10]

$$\Delta P_i = R_i Q_i^2 (i = 1,2,\dots,n) \tag{1}$$

$$\sum_{i=1}^{n} a_{ki} Q_i = 0 (k = 1,2,\dots, j-1) \tag{2}$$

A node matrix may be represented, as shown in equation 3, in which a_{ki} is the general element of the matrix [11]. It equals 1 if the flow direction is such that it passes through branch *i* and enters node *k*. But, it equals -1 if the air goes through branch *i* after it leaves node *k*. When there is no intersection between the branch and node a_{ki} is considered to be zero.

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1i} & \dots & a_{1n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ a_{k1} & \dots & \dots & a_{ki} & \dots & a_{kn} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ a_{(j-1)1} & \dots & \dots & a_{(j-1)i} & \dots & a_{(j-1)n} \end{bmatrix} \tag{3}$$

Equations (1) and (2) are used if the unknowns are the branches' airflows, but if the pressures at nodes are the unknowns these equations should be rearranged for pressure [12].

Equation (4) can be applied to each loop:

$$\sum_{i=1}^{n} C_{oi} \Delta P_i = 0 (o = 1,2,\dots,l) \tag{4}$$

where l is the number of loops, and the values of C_{oi} (the elements of the matrix in equation 5) are defined as: $C_{oi} = 1$ if branch i is contained in loop *o*, and possesses the same flow direction, $C_{oi} = -1$ if branch i is contained in loop *o*, but has the opposite flow direction, and $C_{oi} = 0$ if branch i is not contained in loop *o*.

$$B = \begin{bmatrix} C_{11} & C_{12} & \dots & C_{1i} & \dots & C_{1n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ C_{o1} & \dots & \dots & C_{oi} & \dots & C_{on} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ C_{l1} & \dots & \dots & C_{li} & \dots & C_{l.n} \end{bmatrix} \tag{5}$$

III. FURTHER DEVELOPMENT TO MINE VENTILATION NETWORKS

It is essential to include a source of energy for circulation of the air through the mine network. For that reason, a fan is normally installed at the entrance of the mine, normally a shaft or a tunnel. Sometimes, booster fans are also used on long airways deadlocks. The main fan is usually radial type while the booster fans are auxiliary type and installed inside the branches [13]. Furthermore, it is literally possible to add a new virtual loop to the network. The virtual loop (the dash line in Figure 1) connects the entrance airways to the exit airways and includes the main shafts and tunnels and a few branches. The airflow and pressure distributions in a ventilation network are controlled by suitably placing the fans, doors, and regulators [14]. Taking the virtual loop, as depicted in Figure 1, into consideration one would be able to further develop the energy conservation equations to [10]:

$$\sum_{i=1}^{n} C_{oi} R_i Q_i^2 - \sum_{i=1}^{n} C_{oi} P_{Fi} \pm P_n = 0 (o = 1,2,\dots,l) \tag{6}$$

Where: P_n is the pressure due to natural ventilation. It takes a negative sign if the natural ventilation flow is in the same direction as the general flow, backing the air flowing clockwise in the loop; it otherwise takes a positive sign. The value of P_n remains constant and is independent of airflow changes. Also P_{Fi} is the pressure due to the fan in branch *i*, whose value can be obtained using the fan characteristic function. Usually, the characteristic curve is given by the manufacturer and can be represented by equation (7) [10]:

$$P_{Fi} = aQ_i + b - cQ_i^2 \tag{7}$$

IV. The Newton-Raphson Method

In this method, a correction to the airflow (Δ_o) is defined and applied to all branches. The energy equation (4), therefore could be rewritten as equation (8) for the loop *o*, bearing in mind that *i* is the number of branches in this loop. This equation is satisfied assuming that the correction factor (Δ_o) is applied to the existing airflows associated with all branches in the same loop. For a small value of (Δ_o) compared to Q_i the additional terms vanish, and solving for (Δ_o) equation (10) will be obtained.

$$\sum_{i=1}^{n} C_{oi}R_i(\,Q_i + C_{oi}\Delta_o)^2 = 0 \;(o = 1,2,\dots,l) \tag{8}$$

$$\sum_{i=1}^{n}(2R_iQ_i + C_{oi}R_i{Q_i}^2) = 0 \tag{9}$$

$$\Delta_o = -\frac{\sum_{i=1}^{n} C_{oi}R_iQ_i{}^2}{2\sum_{i=1}^{n} R_iQ_i} \tag{10}$$

The value for (Δ_o) is generalized in equation 11:

$$\Delta_o^{(m)} = -\frac{\sum_{i=1}^{n} C_{oi}^{(m-1)}R_i{Q_i^{(m-1)}}^2}{2\sum_{i=1}^{n} R_iQ_i^{(m-1)}} \tag{11}$$

Equation 11 should be satisfied for every loop in the network. In this equation, *i* and *o* denote branch and loop indices, respectively, and *m* is the iteration number. The energy equation associated with the *o*th loop can be defined according to equation (12). The denominator in equation (11) is the derivative of numerator. Also, the numerator in equation (10) is the same as F_o (equation 12). Therefore, a combination of the three equations (10, 11, and 12) can be expressed in the matrix form (13):

$$F_o = \sum_{i=1}^{n} C_{oi}R_i\,{Q_i}^2 \tag{12}$$

$$\begin{bmatrix} \frac{\partial F_I^{(m-1)}}{\partial \Delta_I} & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{\partial F_{II}^{(m-1)}}{\partial \Delta_{II}} & 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{\partial F_{III}^{(m-1)}}{\partial \Delta_{III}} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{\partial F_{IV}^{(m-1)}}{\partial \Delta_{IV}} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{\partial F_V^{(m-1)}}{\partial \Delta_V} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{\partial F_{VI}^{(m-1)}}{\partial \Delta_{VI}} \end{bmatrix} \times \begin{bmatrix} \Delta_I^{(m)} \\ \Delta_{II}^{(m)} \\ \Delta_{III}^{(m)} \\ \Delta_{IV}^{(m)} \\ \Delta_V^{(m)} \\ \Delta_{VI}^{(m)} \end{bmatrix} = -\begin{bmatrix} F_I^{(m-1)} \\ F_{II}^{(m-1)} \\ F_{III}^{(m-1)} \\ F_{IV}^{(m-1)} \\ F_V^{(m-1)} \\ F_{VI}^{(m-1)} \end{bmatrix} \tag{13}$$

It is apparent that the approximation done for the individual loops is independent to those computed for the other loops. This approach, also known as Hardy−Cross method, is widely used due to simplicity. However, in the Newton - Raphson method, the value of (Δ_o) associated with the *o*th loop is determined taking those associated with the other loops into account at the same time. Similar computation has been done for correcting the air pressures associated with the nodes connecting all branches [15]. Also the corrections are done for the airflows associated with the common branches connecting the loops. The matrix form for this method is given in equation (14). As can be seen, the diagonal matrix (13) is now changed to a normal form (14) because the derivative of the energy equation is considered against all parameters involved in the iteration process. The approximation of the airflow in each loop in the *m*th iteration is done according to the energy equation written for the same loop in the *(m-1)*th iteration in addition to those of other loops.

$$\begin{bmatrix} \frac{\partial F_I^{(m-1)}}{\partial \Delta_I} & \frac{\partial F_I^{(m-1)}}{\partial \Delta_{II}} & \frac{\partial F_I^{(m-1)}}{\partial \Delta_{III}} & \frac{\partial F_I^{(m-1)}}{\partial \Delta_{IV}} & \frac{\partial F_I^{(m-1)}}{\partial \Delta_V} & \frac{\partial F_I^{(m-1)}}{\partial \Delta_{VI}} \\ \frac{\partial F_{II}^{(m-1)}}{\partial \Delta_I} & \frac{\partial F_{II}^{(m-1)}}{\partial \Delta_{II}} & \frac{\partial F_{II}^{(m-1)}}{\partial \Delta_{III}} & \frac{\partial F_{II}^{(m-1)}}{\partial \Delta_{IV}} & \frac{\partial F_{II}^{(m-1)}}{\partial \Delta_V} & \frac{\partial F_{II}^{(m-1)}}{\partial \Delta_{VI}} \\ \frac{\partial F_{III}^{(m-1)}}{\partial \Delta_I} & \frac{\partial F_{III}^{(m-1)}}{\partial \Delta_{II}} & \frac{\partial F_{III}^{(m-1)}}{\partial \Delta_{III}} & \frac{\partial F_{III}^{(m-1)}}{\partial \Delta_{IV}} & \frac{\partial F_{III}^{(m-1)}}{\partial \Delta_V} & \frac{\partial F_{III}^{(m-1)}}{\partial \Delta_{VI}} \\ \frac{\partial F_{IV}^{(m-1)}}{\partial \Delta_I} & \frac{\partial F_{IV}^{(m-1)}}{\partial \Delta_{II}} & \frac{\partial F_{IV}^{(m-1)}}{\partial \Delta_{III}} & \frac{\partial F_{IV}^{(m-1)}}{\partial \Delta_{IV}} & \frac{\partial F_{IV}^{(m-1)}}{\partial \Delta_V} & \frac{\partial F_{IV}^{(m-1)}}{\partial \Delta_{VI}} \\ \frac{\partial F_V^{(m-1)}}{\partial \Delta_I} & \frac{\partial F_V^{(m-1)}}{\partial \Delta_{II}} & \frac{\partial F_V^{(m-1)}}{\partial \Delta_{III}} & \frac{\partial F_V^{(m-1)}}{\partial \Delta_{IV}} & \frac{\partial F_V^{(m-1)}}{\partial \Delta_V} & \frac{\partial F_V^{(m-1)}}{\partial \Delta_{VI}} \\ \frac{\partial F_{VI}^{(m-1)}}{\partial \Delta_I} & \frac{\partial F_{VI}^{(m-1)}}{\partial \Delta_{II}} & \frac{\partial F_{VI}^{(m-1)}}{\partial \Delta_{III}} & \frac{\partial F_{VI}^{(m-1)}}{\partial \Delta_{IV}} & \frac{\partial F_{VI}^{(m-1)}}{\partial \Delta_V} & \frac{\partial F_{VI}^{(m-1)}}{\partial \Delta_{VI}} \end{bmatrix} \times \begin{bmatrix} \Delta_I^{(m)} \\ \Delta_{II}^{(m)} \\ \Delta_{III}^{(m)} \\ \Delta_{IV}^{(m)} \\ \Delta_V^{(m)} \\ \Delta_{VI}^{(m)} \end{bmatrix} = -\begin{bmatrix} F_I^{(m-1)} \\ F_{II}^{(m-1)} \\ F_{III}^{(m-1)} \\ F_{IV}^{(m-1)} \\ F_V^{(m-1)} \\ F_{VI}^{(m-1)} \end{bmatrix} \tag{14}$$

V. The Linear Theory Method

The Linear Theory is used for solving the algebraic and nonlinear differential equations. Equation (15) shows a common form of the Linear Theory [12]. In this equation, the relation of a function to the *(k+1)*th power is given with the same function to the *k*th power. This is the basis of Linear Theory method.

$$\beta^k\psi^k = \beta_0^k\psi_0^k + \beta_0\left(\psi^{k+1} - \psi_0^k\right) + \psi_0\left(\beta^{k+1} - \beta_0^k\right) \tag{15}$$

The Linear Theory function reconciles the airflows associated with all branches in successive iterations. The rate of convergence in this method is higher than those in the other two methods [17].

The initial values should not necessarily be given in this method. This is also an advantage, especially for large networks in which any errors in the initial guess may lead to substantial divergences. It is noteworthy to mention that the head losses in all branches, which were previously represented as nonlinear equations are now converted to linear equations, as in equation (16) [18].

$$\Delta P_i = \left[R_i Q_{i0}^{2-1}\right] Q_i = \left[R_i Q_{i0}\right] Q_i = R_i^* Q_i \qquad (16)$$

The linear Theory method requires that some apparent changes to be done on the previously given energy equations (6). The term associated to the fans may become similar to that of the branch energy losses. For instance, the energy equation of the *o*-loop can be given as equation (17):

$$\sum_{i=1}^{n} C_{oi} R_i Q_i^2 - \sum_{i=1}^{n} C_{oi}\left(cG_i^2 + P_0\right) \pm P_n = 0 \left(o = 1,2,\dots,l\right) \qquad (17)$$

$$G_i = Q_i - \frac{a}{2c} \qquad (18)$$

$$P_0 = b + \frac{a^2}{4c} \qquad (19)$$

Where P_n is the natural ventilation pressure, which could be either in the same direction as the fan or in the opposite direction of the fan. Beside, for linearization of the term cG_i^2, equation (20) which is similar to equation (16) can be used [18].

$$cG_i^2 = cG_{i0} G_i = K_i G_i \qquad (20)$$

Where K_i is analogous to R_i in equation (16). Then the number of linear equations will be the total number of loops and nodes. These equations will create a $n \times n$ system of linear equations as shown in matrix form (21):

$$\begin{bmatrix} a_{11}^{(m-1)} & a_{12}^{(m-1)} & \cdots & a_{116}^{(m-1)} \\ a_{21}^{(m-1)} & a_{22}^{(m-1)} & \cdots & a_{216}^{(m-1)} \\ \vdots & \vdots & \vdots & \vdots \\ a_{81}^{(m-1)} & a_{82}^{(m-1)} & \cdots & a_{816}^{(m-1)} \\ C_{11}^{(m-1)} R_1^{*(m-1)} & C_{12}^{(m-1)} R_2^{*(m-1)} & \cdots & C_{116}^{(m-1)} R_{16}^{*\,(m-1)} \\ C_{21}^{(m-1)} R_1^{*(m-1)} & C_{22}^{(m-1)} R_2^{*(m-1)} & \cdots & C_{216}^{(m-1)} R_{16}^{*\,(m-1)} \\ \vdots & \vdots & \vdots & \vdots \\ C_{61}^{(m-1)} R_1^{*(m-1)} & C_{62}^{(m-1)} R_2^{*(m-1)} & \cdots & C_{616}^{(m-1)} R_{16}^{*\,(m-1)} \end{bmatrix}_{16\times16}$$

$$\times \begin{bmatrix} Q_1^m \\ Q_2^m \\ \vdots \\ Q_{16}^m \end{bmatrix}_{16\times1} = \begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \\ C_{616}^{(m-1)} \left(P_0 + R_{16}^{*\,(m-1)} \dfrac{a}{2c}\right) \pm P_n \end{bmatrix}_{16\times1} \qquad (21)$$

In this equation system, the Node Continuity Equations can be obtained from multiplying the upper rows of the coefficient matrix by the variable matrix (i.e. the unknown values of the airflows). Also, the energy equations associated with each loop can be obtained from multiplying the lower rows of the coefficient matrix by the variable matrix. Note that the lowest row in the coefficient matrix, which includes the fans and the natural ventilation, is the most inclusive term exclusively introduced to the network. Some features of the matrix are as follows:

- It is defined to include most of the decisive terms in the network, where all the nodes and loops equations can be identified.
- More than one fan can be selected in the virtual loop, if needed. The natural ventilation which exists in many mines is included, and similar equations could be defined for those loops with fans or booster fans.
- The negative/positive effect of natural ventilation in accordance to that of the mechanical ventilation is also included.

The calculation will continue until the equation (22) is satisfied. Then, the operation stops and the final values associated with the branches' airflows will be the answers [19].

$$\varepsilon = \frac{\sum |Q_i - Q_{i-1}|}{\sum Q_{i-1}} \leq 0.005 \qquad (22)$$

VI. A Numerical Example

These are for the ventilation network shown in Figure (1), which will be used in conjunction with equations (12), (13), and (22) to do a comparative study of the Newton-Raphson and Linear Theory methods. Also given is the main fan characteristic curve as in equation (23):

$$H = -1084.51 + 29.28Q - 0.16Q^2 \qquad (23)$$

Table (1) shows the results obtained for all branches iteratively using the Newton-Raphson method. The values given in the first row (i.e. the 1st iteration) are the initial guess quantities chosen according to the nodes continuity equations. Also shown in Table (2) are the error values from the Newton-Raphson method using equation (24):

$$\delta = \frac{\sum |Q_i - Q_{i-1}|}{n} \leq 0.01 \qquad (24)$$

To solve the example by the Linear Theory an identical initial value (i.e. the airflow $= 100\, m^3/s$) for all branches is assumed. Table (3) shows the solved values obtained for all branches using the Linear Theory method. Also shown in Table (4) are the iterative error quantities resulted from the Linear Theory method using equation (24).

TABLE I. THE VALUES OBTAINED FOR ALL BRANCHES USING THE NEWTON-RAPHSON METHOD

Branch No.		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Resistance		0.5	13.5	13	16.2	0.6	16.2	15.6	16.2	0.6	16.2	16.2	16.2	15.6	16.2	0.6	0.6
Iteration	**1**	100	50	25	47	50	25	25	22	53	50	62	40	25	13	12	100
	2	145.67	46.25	41.52	44.80	99.42	38.16	4.73	3.28	100.87	42.89	38.73	35.45	61.26	65.42	-4.16	145.67
	3	129.44	43.52	47.16	40.80	85.92	35.31	-3.64	-6.36	88.64	31.67	30.48	36.84	50.61	51.80	-1.19	129.44
	4	123.59	42.07	46.54	40.21	81.52	34.64	-4.47	-6.33	83.38	30.17	29.88	36.21	46.88	47.17	-0.29	123.59
	5	123.10	41.94	46.43	40.12	81.16	34.54	-4.49	-6.61	82.98	30.06	29.82	36.13	46.61	46.85	-0.23	123.10
	6	123.10	41.94	46.43	40.12	81.16	34.54	-4.49	-6.31	82.98	30.06	29.82	36.13	46.61	46.85	-0.23	123.10

TABLE II. THE ITERATIONS ERRORS OBTAINED BY NEWTON-RAPHSON METHOD

Iteration number	**1**	**2**	**3**	**4**	**5**	**6**
Sum of the branches errors	-	403.02	139.52	37.54	4.38	≤0.01
Average of the branches errors	-	25.19	8.72	2.35	0.27	≤0.01

TABLE III. THE SOLVED VALUES OBTAINED FOR ALL BRANCHES USING THE LINEAR THEORY METHOD (M^3/S)

Branch No.		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Resistance		0.5	13.5	13	16.2	0.6	16.2	15.6	16.2	0.6	16.2	16.2	16.2	15.6	16.2	0.6	0.6
Iteration	**1**	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	2	151.09	47.35	43.07	44.05	103.74	35.76	4.28	0.99	107.03	40.04	35.53	34.54	67.96	72.49	-4.51	151.09
	3	163.47	56.63	52.09	54.17	117.38	44.93	8.26	4.83	121.52	43.39	41.73	39.25	79.17	83.32	-7.41	163.47
	4	146.25	45.64	50.36	43.28	108.74	39.80	-2.34	1.35	95.45	37.46	33.29	34.64	61.65	61.81	-6.17	146.25
	5	131.14	42.68	48.17	41.42	86.76	36.12	-5.49	-7.75	89.02	30.63	29.57	37.32	50.64	51.70	-1.06	131.14
	6	127.38	42.35	47.65	41.62	85.33	35.48	-4.30	-6.53	88.56	31.18	30.07	36.60	51.85	52.96	-1.11	127.38
	7	124.58	42.43	45.53	40.68	82.53	34.93	-4.71	-6.24	84.38	31.02	29.76	36.29	47.52	48.76	-0.59	124.58
	8	123.59	42.05	46.54	40.21	81.53	34.64	-4.48	-6.33	83.37	30.15	29.87	36.20	46.90	47.17	-0.28	123.59
	9	123.10	41.94	46.43	40.12	81.16	34.54	-4.49	-6.31	82.98	30.06	29.82	36.13	46.62	46.85	-0.23	123.10
	10	123.10	41.94	46.43	40.12	81.16	34.54	-4.49	-6.31	82.98	30.06	29.82	36.13	46.62	46.85	-0.23	123.10

TABLE IV. THE ITERATIVE ERROR QUANTITIES RESULTED FROM THE LINEAR THEORY METHOD

Iteration number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Sum of the branches errors	-	891.40	137.50	171.22	121.03	17.80	26.80	10.05	3.04	≤0.01
Average of the branches errors	-	55.71	8.59	10.70	7.56	1.11	1.67	0.63	0.19	≤0.01

As can be seen, the Newton-Raphson method would yield a satisfactory error after five iterations. However, the Linear Theory method would do the same after nine iterations. This implies a higher rate of convergence for the Newton's method.

The initial guess for Q_{i0} is considered to be equal to the average of the apparent final answers. Because, when this guess, which is the same for all the branches, differs significantly from the average of the final answer it will be less likely to suppress divergence in the iteration process. Such divergence is likely to occur when fans are used in the network[4]. It has also been shown that to reduce the likelihood of oscillation for the real answers the mean of the two previous iterations may be used for every branch in the sequence [18].

For comparison, the iteration error against the number of iterations is plotted in Figure 2 for both methods.

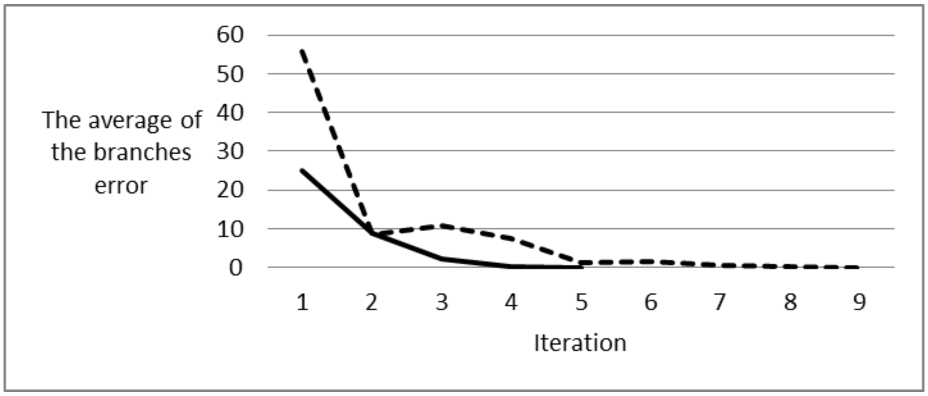

Fig. 2. The iteration error against the number of iterations for the Newton-Raphson method (continuous line) and the linear Theory method (discrete line)

As can be seen in Figure 2, in the first iteration implemented by the Newton-Raphson method, the value of the error is lower in magnitude. It also decreases smoothly to yield the answer. In the linear Theory method, the iteration error starts with higher value and changes with some oscillation to reach the answer. This oscillation can lead to divergence in large networks. It is suggested that in the Linear Theory the next trial solution should be the average of the previous two solutions equation(25):

$$Q_n = \frac{Q_{n-1} + Q_{n-2}}{2} \tag{25}$$

Alternatively, it may be suggested equation (26):

$$Q_n = \sqrt{Q_{n-1} \times Q_{n-2}} \tag{26}$$

which works just as satisfactorily in removing the oscillatory nature of successive solutions.

It can adequately deal with large systems of equations and has the advantage that the first approximation to the solution does not need to satisfy continuity conditions and the initial values may be arbitrary. Wood and Charles [20] observed an oscillatory nature in successive estimates close to the converged solution and suggested the next trial solution to be the average of the previous two solutions.

VII. Conclusion

The large number of variables in mine ventilation networks implies the need for using the approximate methods. The matrices of nodes and loops are shown to be good characteristics of the network. Using the equations in the matrices form and applying the approximate methods based on iteration could be the core of simple programming tasks in mine ventilation network analysis. The possibility of the initial guesses for the branch airflow being incorrect in the Newton-Raphson method is lower. This is because, in comparison with the water and gas networks, the mine ventilation networks are less expanded. Therefore, in comparison with the Linear Theory method, the Newton-Raphson method converges faster. On the other hand, when using computational tools and software the advantage of faster convergence becomes less important and therefore the Linear Theory method will be more preferred.

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References

[1] Cross H. Analysis of Flow in Networks of Conduits or Conductors. Engineering Experiment Station, University of Illinois, Urbane, 1936; 286- 295.

[2] Scott DR, Hinsley FB. Ventilation Network Theory. Colliery Engineering, London, 1951.

[3] Wood DJ, Charles COA. Hydraulic Network Analysis Using Linear Theory. Journal of Hydraulics Division, ASCE, 1972; 98(HY7): 1157-1170.

[4] Jeppson RW, Tavallaee A. Pumps and Reservoirs in Networks by Linear Theory. Journal of Hydraulics Division, ASCE, 1975; 101(HY7): 576-580.

[5] Bhamidipati SS, Procarione JA. Linear Analysis for the Solution of Flow Distribution Problems in Mine Ventilation Network. *Proceedings of the North American 9th US Mine Ventilation Symp*, 1985, 646-654.

[6] M. Kolarczyk, "Determination of a matrix column of air volume output sensitivity to changes in side branches resistance in a mine ventilation network," GeoScience Engineering, Vol. LIII, No. 1, pp 25-35, 2007.

[7] X. Star Wu and E. Topuz, "Analysis of Mine Ventilation Systems Using Operations Research Methods," Int. Trans. Opl Res., Vol. 5, No. 4, pp. 245-254, 1998.

[8] S. Yuna and W. Hai-ning, "Study and Application on Simulation and Optimization System for the Mine Ventilation Network," Procedia Engineering, Vol. 26, pp 236 – 242, 2011.

[9] F. Wei, Z. Fangping, and L. Huiqing, "The use of 3D simulation system in mine ventilation management," Procedia Engineering, Vol. 26, pp. 1370-1379, 2011.

[10] McPherson MJ. Subsurface Ventilation and Environmental Engineering. Chapman & Hall, UK, 1993.

[11] Yun QX, Huang KM. Determination of Ventilation System for Mines by Genetic Algorithm. Proceedings of the 6th Environmental Issues and Management of Waste in Energy and Mineral Production Symp, , 2000, 725-733.

[12] Madani H, Maleki B. Analysis of Mines Ventilation Network by Newton-Raphson method based on the H equations. Journal of Mine Eng. 2008; 3(5): 71-77.

[13] Hartman HL, Mutmansky JM, Wang YJ. Mine Ventilation and Air Condition. Wiley, 1982.

[14] Lowndes IS, Fogarty T, Yang ZY. The application of genetic algorithms to optimize the performance of a mine ventilation network: the influence of coding method and population size. Springer-Verlag, 2004.

[15] Madani H, Maleki B. Analysis of Mines Ventilation Network by Newton-Raphson method based on the ΔQ equations. Journal of AmirKabir University, 2007; 66c.

[16] Phillips GM, Taylor PJ. Theory and Applications of Numerical Analysis. Academic Press, 1980.

[17] Jeppson RW. Steady Flow Analysis of Pipe Networks, An Instructional Manual, Utah State University, 1974.

[18] Ellis DJ, Simpson AR. Convergence of Iterative Solvers for the Simulation of a Water Distribution Pipe Network. Department of Civil and Environmental Engineering, The University of Adelaide, Research Report No. R138, 1996.

[19] Savic DA, Walters GA. An Evolution Program for Pressure Regulation in Water Distribution Networks. Report Number: 94/15, University of Exeter, United Kingdom, 1994.

[20] Wood DJ, Charles COA. Optimization of mine ventilation and methane recovery. European Commission technical coal research Mining operations, EUR 17392 EN, 1993.

Stable Beneficial Group Activity Formation

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***Abstract*—Computational models are one of the very powerful tools for expressing everyday situations that are derived from human interactions. In this paper, an investigation of the problem of forming beneficial groups based on the members' preferences and the coordinator's own strategy is presented . It is assumed that a coordinator has a good intention behind trimming members' preferences to meet the ultimate goal of forming the group. His strategy is justified and evaluated by Nash stability. There are two variations of the problem: the Anonymous Stable Beneficial Group Activity Formation and the General Stable Beneficial Group Activity Formation. The computational complexity of solving both variations has been analyzed. Finding stable groups needs non-polynomial time algorithm to be solved. A polynomial time solution is presented and enhanced with examples.**

***Keywords*—computational models; group formation; members' preferences; Nash stability**

I. INTRODUCTION

Capturing human behavior and translating it into a model has been the area of research since centuries. The motivation was to build systems that can percept, learn, adapt and take right decisions as well as predict future actions.

This seed plants itself deeply into science, it produced rich mathematical social sciences that had empowered the introduction of social computing science.

Many powerful systems were created as the result of merging social behavior and computational models, examples are: emails, social networks, online gaming, political parties formation, healthcare systems, speaker identification, query expansion techniques [1][7][17],etc.

One of the most interesting areas in this perspective is collective intelligence that refers to the kind of intelligence that is aroused as an effect of the collaborative efforts of many agents to achieve a single goal taking into account competition among them [11]. This concept (although not so named) was referred to in Hedonic Coalitions that was introduced in 1980 [6]. It considered how social coalitions are structured to meet certain preferences. A concept that is rooted in the work of Marquis de Condorcet in 1785, who investigated the probability of making a correct decision by the cooperation of several members [5]. Figure 1 shows the fields of science that branches from collective intelligence [18][12].

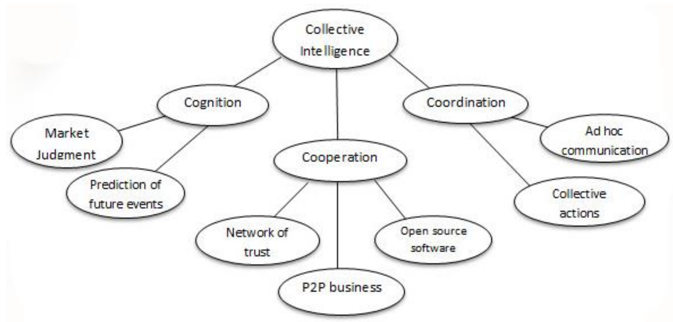

Fig. 1. Collective Intelligence Branches

In the scope of this paper, an investigation of the area of beneficial group activities formation that can be classified under coordinating collective actions is presented.

Scheduling a set of activities has been studied thoughtfully in the literature; one of the new trends in this field is how to schedule activities that each of them should compromise a set of agents.

To formulate this problem, let's consider the social situation that an event coordinator is trying to organize multiple distributed activities that are held in different places at different time intervals. There are no precedence relationship between these activities. They are supposed to be independent on each other; they don't share the same resources.

The coordinator's responsibility is to invite/assign one or more agent to each activity. Agents are not considered as peers rather each agent is supposed to contribute in that activity by a certain score/weight/benefit. Thus, the organizer's goal is to invite/assign as many agents as possible to maximize the amount of contribution i.e. benefit of the activity.

The coordinator should consider the agents' preferences for both the activity and the number of participants in that activity, thus the coordinator should assign agents to activities on basis of their preferences over group size.

Each agent is allowed to have preferences over the identities of other invitees, e.g. one agent might only come if his/her colleague is coming and may not prefer to come if a competitor agent comes.

The coordinator should make sure that each agent's preferences are met but without contradicting with the ultimate goal of forming the group i.e. maximizing benefit.

Consider the situation where a professor is trying to create multiple research groups on different topics within his field, for example. One of the main concerns when forming such assignments is Stability. It is desirable in many systems that contain scheduling, QoS, clustering, data mining [2][14][16], pattern matching [15], etc. But, it is not always possible to maintain a stable assignment. This motivates investigating the problem and evaluating the complexity of finding a feasible solution.

The paper is organized as follow: Section II presents related literature. Section III demonstrates the Stable beneficial Group Activity Formation Problem. The Anonymous variation of the problem is investigated in section IV along with definitions and notations in addition to examples and algorithms to solve the problem. Section V introduces the Stable beneficial Group Activity Formation Problem along with its definitions, example and algorithm. The conclusion is given in section VI.

II. Related Litreture

Group formation itself has been studied thoughtfully in the literature, different algorithms were proposed to best cluster the members into groups based on attributes they hold [13].

The General Group Activity Selection Problem (GASP) was formally introduced in [4]. An organizer tries to organize several activities, each activity is accomplished by several agents. An agent can participate in exactly one activity at a time, the agent is allowed to select an activity to participate in and the preferred group size for that activity. The authors analyzed the computational complexity of this problem in different cases.

The authors in [8] introduced the Stable Group Scheduling Problem where an organizer is trying to schedule an event that happens over multiple time slot. An agent is allowed to choose the desired time slot to join event and the preferred group size for the activity in that time slot. They analyzed the complexity of this problem for both the non-strategic agents (i.e. agents that reveal their preferences without further modifications) and strategic agents (agents that may change their preferences afterwards).

They found that for the non-strategic agent's variation, a polynomial time algorithm that determines whether a stable schedule exists, and if it does, determine the maximum number of schedules exist.

They extend their work in [9], by introducing the *Stable Invitation Problem* in two variations: the anonymous and non-anonymous. They consider the problem of how to invite multiple agents to a single event taking into account their preferences over a number of invitees; and who the invitees are. They provide a number of complexity results with respect to stability, and also consider strategic behavior of the agents.

In [3], Darmann re-introduced the General Group Activity Selection Problem, considering the agents' ordinal preferences where each agent can determine the (activity, group size) pair. He analyzed the computational complexity for finding a stable assignment using k-approval scores and considering Nash and core stability.

The approach in this work differs from the approaches stated above by considering the situation of more than one independent activity. To best reflect the problem, the organizer himself has a goal to form the group/invitation which is maximizing benefit. Furthermore, in this approach the agents are not treated as peers, instead, each agent is assumed to contribute in the group to some extent.

It is worth mentioning that these problems are inspired by the Hedonic Games [6].

III. Stable Beneficial Group Activity Formation Problem

A professor creates multiple research groups on different topics within his field, he/she invites students to join these groups. His/her objective is to maximize the benefit from this group by:

1) maximizing the number of attendees in each group.
2) inviting only students that has knowledge in the area.

Students are allowed to have preferences over the group size as well as the colleagues in the group. The professor's strategic considers Nash stability in forming stable groups. There are two variations of the problem, the Anonymous Beneficial Group Activity Formation ABGA and the General Beneficial Group Activity Formation GBGA.

IV. Anonymous Beneficial Group Activity Formation Abga

In this variation, students don't have preferences over identities of the invitees but they only care about the size of the research group they are invited into.

A. Definitions and Notations

*Definition 1.*An instance of the Beneficial Group Activity Formation ABGA is a tuple (A, E, P) where,

$A = \{a_1, a_2,\ldots,a_n\}$is a set of n agents,

$E = \{e_1, e_2, \ldots, e_m\}$ is a set of m activities (Research Groups)

P is an n-tuple of preferences of agents where $P = (P_1, P_2,\ldots, P_n)$. For each agent a_i,, define P_i to be a total preorder ($\succcurlyeq_i$)on the set of preferences, the agents may prefer not coming if $p_i=0$.

For any $p_1,p_2 \in (P\backslash\{0\})$, $p_1 \succcurlyeq_i p_2$means that agent a_i prefers joining the group if the number of attendees in the group is p_1 (including himself) to attending if the number of attendees is p_2 attendees (including himself).

Any subset of A is a solution to ABGA-instance (N,E,P), is called G a 'Beneficial Group'.

Definition 2. Agent's benefit, in this example, student's knowledge within the area of the group is defined in terms of (courses studied , interest , publications) and is expressed as a score in the knowledge-matrix. The higher the score is, the more knowledge the student has within this area. Knowledge matrix B is a two-dimensional matrix of size (|A|*|E|) i.e.(n*m). The professor invites all students that are expected to maximize the contribution of the group, by inviting only students whose knowledge within the area of the group exceeds T, a threshold score determined by the professor.

$\forall\ a_i \in G, B(a_i, E_j) > T$.

Definition 3. The objective is to invite a subset of agents subject to stability constraints considering agents' preferences over group size. An instance (A, E, P) is said to be Nash stable, if:

1) If everyone who's invited is willing to participate, then G is Individually-Rational.

G is Individually-Rational (IR) if $\forall a_i \in G$, $|G| \succcurlyeq 0 \wedge B(ai, E_k) > T$.

2) If everyone who's not invited is unwilling to join, G is Regret-Free RF if $\forall a_i \notin G$, $0 \succcurlyeq (|G| + 1)$.

In other words, Individual-Rationality means that all the invited students prefer to come to not coming and has knowledge in the area of the research group as their contribution exceeds T. While Regret-Free means that all agents who are not invited, don't prefer to come.

G is said to be Nash stable if it is both IR and RF.

The professor's goal is to maximize the number of members in stable beneficial groups.

B. Examples of ABGA

Example1.Example of anonymous preferences.

- A Basketball team preferences over group size.

  A1: $10 \succ 5 \succ 0 \succ 1,2,3,4$ [1]

- A Soccer team preferences over group size.

  A2:$22 \succ 11 \succ 0 \succ 1,2,3,4,5,6,7,8,9,10$

Example2.Finding a Stable Group.

Consider agents a_1, a_2, $a_3$have knowledge in two areas and the professor is trying to compose two Research GroupsG_1 and G_2. The students preferences over group size are as follows:

  - P_1: $1 \succ 0 \succ 2$
  - P_2: $3 \succ 0 \succ 1$
  - P_3: $2 \succ 0 \succ 1$

- Inviting no one, i.e. G={}, is not RF because of a_1 whose preference is ($1 \succ 0$), he prefers coming alone to not coming at all.

Recall that G is RF if $\forall a_i \notin G$, $0 \succcurlyeq (|G| + 1)$

- Inviting only a_1, i.e. G={a_1} is not RF because of a_3 whose preference is ($2 \succ 0$), he prefers joining someone else to not coming. Investigate G={a_2,a_3}, if it is stable, then G={a_1} is stable.

G_1={a_2,a_3}is stable because it is both IR and RF. Thus G_2={a_1} is stable.

- Inviting only a_2, i.e. G={a_2} is not IR because of a_2 whose preference is ($0 \succ 1$), he would rather not come to coming alone.
- Inviting only a_3, i.e. G={a_3} is not IR because of a_3 ($0 \succ 1$)
- Inviting a_1,a_2, i.e. G={a_1,a_2} is not IR because of a_1 preference ($0 \succ 2$), he prefers not coming to coming with only another person.
- Inviting a_1,a_3, i.e. G={a1,a2} is not IR because of a1.
- Inviting a_1,a_2, i.e. G={a_1,a_2} is not IR because of a_1.
- It is not possible to invite the three of them as it contradicts the professor's constrain of constructing two groups.

Thus, only one assignment is possible.

G1={a_2,a_3} and G2={a_1}.

Example2.Stable Group may not exist

Consider studentsA_1 and $A_2$are invited to only one Research Group E_1. Students preferences over group size are as follows:

  - P_1: $1 \succ 0 \succ 2$
  - P_2: $2 \succ 0 \succ 1$

- Inviting no one, i.e. G={}, is not RF because of $a_1$preference ($1 \succ 0$)
- Inviting only a_1, i.e. G={a_1} is not RF because of a_2 preference ($2 \succ 0$).
- Inviting only a_2, i.e. G={a_2} is not IR because of a_2 preference ($0 \succ 1$)
- Inviting a_1,a_2, i.e. G={a_1,a_2} is not IR because of a_1 preference ($0 \succ 2$)

C. ABGA Algorithm and Complexity Analysis

1) Exhaustive Algorithm Complexity

Algorithm 1: To find the maximum number of stable groups

Input:

1. A set of students.
2. P Students' preferences as tuples.
3. E set of Research Groups.
4. B knowledge matrix.
5. T knowledge threshold.

Output: BG a subset of A

```
{  // Definitions
       int n              // number of students
       int m       // number of activities
```

[1] a1 prefers joining the basketball team if the number of members (including himself) is 10, more than he prefer joining if the members (including himself) is 5. And he also prefers joining the team if the number of members (including himself) is 5, more than not coming. And he would rather not come if the number of members (including himself) is less than 5.

```
        int p              // size of preferences tuple
        int Students[n] //1-dimension array of students
        int Activity[m]  // 1-dimension array of activities
        int Benefit[n,m]
        int Pref[n,p]      // preferences matrix
        G[ ], S[ ]      // temporary vectors
  // Groups construction
        For j = 1 to m
        For i= 1 to n
                If ( B(i , j) > T )
                        Then Students[i] ∈ G_j[]
//Checking size compatibility of each group
        For j = 1 to m
                PSize_j= |G_j|  // preferred size of group
                For i= 1 to PSize_j
                {
                {
                For j= 1 to n
                For k= 1 to p
                If (i = Pref[j,k) then  Students[n]  ∈S_i[ ]
                }
                If |S_i[ ]| = PSize_j then S_i⊂ BG_j
               }
        Return BG_j
        }
}
```

To check whether a group G is stable, assuming that the professor invited only beneficial students, consider:

- $\forall a_i \in G$, check whether $|G| \succcurlyeq_i 0$
- $\forall a_i \notin G$, check whether $0 \succcurlyeq_i (|G| + 1)$

This checking is repeated at most |A|*|E| times, i.e. for each of the agents and groups.

Thus to check all the 2^n subsets of A, the algorithm's complexity takes at most $O(n*m*2^n)$ which means that the algorithm needs non-polynomial time to find the solution.

2) Efficient Algorithm Complexity

It is possible to check whether a group G is stable, assuming that the professor invited only beneficial students, then consider Algorithm 2:

Algorithm 2: To find the maximum number of stable groups

Input:

1. A set of students.
2. P Students' preferences tuple.
3. G set of Research Groups.
4. A professor's preferred group size X.

Output: G a subset of A

```
  {   For j = 1 to m
      For i= 1 to n
      If {Students[i] ∈G_i : (X ≽_j 0)}≥ X
      If {Students[i] ∈G_i: (0 ≽_j X)∧ ((X+1) ≽_j 0) } = 0
      If {Students[i] ∈G_i: (X ≽_j 0)∧ ((X+1) ≽_j 0) } ≤ X
         Return G_i is stable
  }
```

This algorithm takes only $O(m*n^2)$ operations which is so much better than the exhaustive search algorithm.

V. General Beneficial Group Activity Formation Problem GBGA

This is a generalization of the ABGA. In addition to group size, each student allowed to have preferences over the identities of the colleagues joining the same group:

- Colleagues who is comfortable working with: *Wish list*
- Colleagues who is undesirable working with: *Reject list*

The professor strategic is to consider Nash stability in forming stable groups. His/her objective is to maximize the benefit from this group by:

1) maximizing the number of attendees in each group.
2) inviting only students that has knowledge in the area.

A. Definitions and Notations

An instance of the General Group Activity Formation ABGA is (A, E, P= (P_1, P_2,…, P_n), W,R), where

A = {a_1, a_2, …, a_n} is a set of agents.

E = {e_1, e_2, …, e_m} is a set of m activities (Research Groups)

P is an n-tuple of preferences of agents where P = (P_1, P_2,…, P_n). For each agent a_i, define P_i to be a total preorder ($\succcurlyeq_i$)on the set of preferences, the agents may prefer not coming if p_i=0.

W_i is prefer set of student a_i where $W_i \subset A$

R_i is reject set of student a_i where $R_i \subset A$

Any subset G of A is a solution to GBGA-instance(A,E,P,W,R), G is a `Beneficial Group'■

Students are allowed to have preferences over:

- Research group size
- Colleagues who is comfortable working with: W-list
- Colleagues who is undesirable working with: R- list

Thus, every potential invitee is either:

- Original-Invitee: invited by the professor as he/she has knowledge within the area or
- Co-Invitee: preferred to be invited by one of the original-invitees as they both have mutual contribution within the area or for any other reasons.

Everyone who is not invited, is not a researcher in the area.

Agents Mutual contribution matrix is defined in terms of two-dimensional matrix M of size (n * n) that represents mutual contribution between agents based on (shared project, publications).

B. Applying Stability Constrains

The professor's ultimate goal is to collect beneficial students in each group to attain group stability. Although he invites only students that has a contribution in the area above a certain threshold, he would agree with an original-invitee to invite a student with less contribution if this co-invitee has previous mutual contribution with the original invitee.

This strategy is adopted from May and Doob work on cooperative learning. They stated that "people who cooperate and work together to achieve shared goals, were more successful in attaining outcomes, than those who strived independently to complete the same goals" [10]. Thus, the professor is willing to:

- not respond to the student's wish to work with a certain colleague if the co-invitee has no knowledge in the area. The professor would agree to invite the co-invitee student a_i if his/her contribution within the area of the group is more than T.

If $a_i \in W_{j,k} \wedge B(a_i , E_k) > T$, then $a_i \in G_j$, where

a_i is the co-invitee student

$W_{j,k}$ is the Wish-list of Student j for activity K

$B(a_i , E_k)$ is the benefit of student a_i for the activity E_k

T is the contribution threshold.

- not respond to the student's wish to reject working with a certain colleague, if the rejected college has knowledge in the area.

If $a_i \in R_{j,k} \wedge B(a_i , E_j) > T$, then $a_i \in G_j,$

where $R_{j,k}$ is the Reject-list of Student j for activity K

- agrees on the student's wish to work with a certain colleague, if the co-invitee has mutual contribution with the original-invitee even if his/her contribution within the area is < T.

If $a_i \in W_{j,k} \wedge (B(a_i , E_j) < T) \wedge (M(a_i,a_j)>T')$, then $a_i \in G_j$

Where T' is a mutual contribution threshold determined by the professor.

C. GBGA Example

A professor is trying to create 3 research groups for 3 areas. He/she has 3 students. The contribution threshold is >4. The mutual contribution threshold is >2. Find the maximum number of groups. The students preferences, contribution and mutual contribution is shown in the matrices in TABLE II.

TABLE I. MUTUAL CONTRIBUTION MATRIX M

Agent	a1	a2	a3
a1	0	1	5
a2	1	0	7
a3	5	7	0

TABLE II. CONTRIBUTION MATRIX B

Agent	Area1	Area2	Area3
a1	9	2	7
a2	1	4	3
a3	6	2	10

TABLE III. PREFERENCES MATRIX

Student	Preferred group size	Prefer List	Reject List
a_1	3>2>0	a_2	a_3
a_2	2>1>0	a_3	0
a_3	4>2>0	a_1	a_2

It is obvious that the preferred size that the three students agree upon is 2.

<u>For Area1,</u>

- Students a_1 and a_3 have acceptable contribution scores, they both would be invited.
- a_1W-list is rejected, because a_2 has little contribution in the area and little mutual contribution with a1.
- a_1W-list is rejected, because a_3 has good contribution in the area.
- a_3W-list and R-List are applicable.
- The resultant group is G1={a_1,a_3}.

<u>For Area2,</u>

- Only students a_2 has acceptable contribution score, he is invited, G_2={a_2}.
- A_2W-list is accepted as a3 has mutual contribution with a_2>2. Thus, G_2={a_2.a_3}.
- A_2 R-List is empty.
- The resultant group is G_2={A_2,A_3}.

<u>For Area3,</u>

- Students a_1 and $a_3$have acceptable contribution scores, they both would be invited.
- a_1W-list is rejected, because $a_2$has little contribution in the area and little mutual contribution with a_1.
- a_1W-list is rejected, because $a_3$has good contribution in the area.
- a_3W-list and R-List are applicable.
- The resultant group is G_1={a_1,a_3}.

D. GBGA Algorithm and Complexity Analysis

Algorithm: To find the maximum number of stable groups.

Input:

1. A set of students.
2. P Students' preferences matrix P.
3. E set of Research Areas.
4. Wish-List W
5. Reject-List R
6. Contribution matrix B
7. Mutual Contribution matrix M.

Output: a subset of BG∈G

```
{ // Definitions
        int n               // number of students
        int m               // number of activities
        int p               // size of preferences tuple
        int Students[n]  //1-dimension array of students
        int Activity[m]  // 1-dimension array of activities
        int Benefit[n,m]
        int Pref[n,p]     // preferences matrix
        G[ ], S[ ]        // temporary vectors

PSize_j= n
For i= 1 to n
For k= 1 to p
{
        For j= 1 to n
        If (PSize_j = Pref[j,k]) then  Students[j] ∈ S_i[ ]
        If |S_i[ ]| = PSize_j then S_i ⊂ G_j
}

For k= 1 to m
For i= 1 to |G_i[ ]|
For j= 1 to |G_i[ ]|
   if (Students[i]  ∈W_k ∧ B(i , k) > T) then Students[i]∈G_j
  else
If (Students[i] ∈R_k ∧ B(i , k) > T) then Students[i]∈G_j
else
If (Students[i]∈W_k ∧ (B(i , k) < T) ∧ M(Students[i] ,Students[j])>T') then Students[i]∈G_j

Return G
}
```

The GBGA algorithm takes only O(m*n*p) operations. It has a polynomial run time complexity.

VI. Conclusion and Discussion

The main contribution of this work is the analysis of the stable beneficial group activity formation problem considering the members' preferences as well as the coordinator strategy. The coordinator is trying to maintain stability in the groups formed while maximizing the overall benefit and balance those metrics to the members' preferences. The formalism of this problem tried to reflect the natural way of composing beneficial groups without relying upon hard constrains in the traditional way. Two variations of the problem and a their computational complexity are presented.

The proposed algorithm, with polynomial running time achieves the same quality of the exhaustive non-polynomial time algorithm that is used for stable beneficial groups formation. The proposed solution made use of the agents' preferences and coordinator's strategy as delimiters of the problem space.

For future research, it is highly encouraged that the researchers formulate the reflection of further extensions of the problem. Examples of extensions are scheduling those groups in different time slots, considering deadline constrain, and forcing penalties on members who change their group membership, etc.

References

[1] Adwan, O., Sleit, A., Qatawneh, M., Huneiti, A., Khalil, T., & Abu, A. L. "Implementing a Total Healthcare Enterprise Resource Planning System". Information-An International Interdisciplinary Journal, pp. 3997-4004, 2013.

[2] Almobaideen, W., Al-Khateeb, D., Sleit, A., Qatawneh, M., Qadadeh, K., Al-Khdour, R., & Hafeeza, H. A. "Improved stability based partially disjoint AOMDV", 2013.

[3] Darmann, A. "Group Activity Selection from Ordinal Preferences". In Algorithmic Decision Theory (pp. 35-51), 2015. Springer International Publishing.

[4] Darmann, A., Elkind, E., Kurz, S., Lang, J., Schauer, J., & Woeginger, G. "Group activity selection problem". In Internet and Network Economics(pp. 156-169), 2012. Springer Berlin Heidelberg.

[5] Douglas J. Amy."Behind the Ballot Box: A Citizen's Guide to Voting System"s. Greenwood Publishing Group. p. 188, 2000.

[6] Dreze, J. H., & Greenberg, J. "Hedonic coalitions: Optimality and stability". Econometrica: Journal of the Econometric Society, 987-1003, 1980.

[7] Hammo, B., Sleit, A., & El-Haj, M. "Effectiveness of query expansion in searching the Holy Quran".The Second International Conference on Arabic Language Processing CITALA'07. , Rabat, Morocco, pp. 1-10. 2007.

[8] Lee, H., & Shoham, Y. "Stable Invitations". arXiv preprint arXiv:1405.7751, 2014.

[9] Lee, H., & Shoham, Y. "Stable group scheduling". In Proceedings of the 2014 international conference on Autonomous agents and multi-agent systems, pp. 1347-1348, 2014.

[10] May, M. and Doob, L. "Cooperation and Competition". New York: Social Sciences Research Council, 1937.

[11] Pierpaolo, B., et al. "Evaluation of multi-agent systems: Proposal and validation of a metric plan." Transactions on Computational Collective Intelligence VII. Springer Berlin Heidelberg, pp. 198-221, 2012.

[12] Rheingold, H. "Smart mobs: The next social revolution". Basic books, 2007.

[13] Salah, I., Sleit, A., Al-Sharaeh, S., Huneiti, A., & Obeed, N. "Efficient Method for Assigning Students to Proper Groups". Editorial Advisory Board e,21(2), pp. 249-358, 2005.

[14] Sleit, A., Al-Akhras, M., Juma, I., & Alian, M. "Applying Ordinal Association Rules for Cleansing Data With Missing Values". Journal of American Science, 5(3),pp. 52-62, 2009.

[15] Sleit, A., AlMobaideen, W., Baarah, A. H., & Abusitta, A. H. "An efficient pattern matching algorithm". Journal of Applied Sciences,7(18), pp. 2691-2695, 2007.

[16] Sleit, A., Qatawneh, M., Al-Sharief, M., Al-Jabaly, R., & Karajeh, O. "Image Clustering using Color, Texture and Shape Features". KSII Transactions on Internet & Information Systems, 5(1), 2011.

[17] Sleit, A., Serhan, S., & Nemir, L. "A histogram based speaker identification technique".First International Conference onApplications of Digital Information and Web Technologies, ICADIWTIEEE, pp. 384-388, 2008.

[18] Surowiecki, J. "The wisdom of crowds". Anchor, 2005.

Network-State-Aware Quality of Service Provisioning for the Internet of Things

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Abstract*—The Internet of Things (IoT) describes a diverse range of technologies to enable a diverse range of applications using diverse platforms for communication. IP-enabled Wireless Sensor Networks (6LoWPAN) are an integral part of IoT realization because of their huge potential for sensing and communication. The provision of Quality of Service (QoS) requirements in IoT is a challenging task because of device heterogeneity in terms of bandwidth, computing and communication capabilities of the diverse set of IoT nodes and networks. The sensor nodes in IoT, e.g., 6LoWPAN, exhibit low battery power, limited bandwidth and extremely constrained computing power. Additionally, these IP-based sensor networks are inherently dynamic in nature due to node failures and mobility. Introduction of modern delay-sensitive applications for such networks has made the QoS provisioning task even harder. In this paper, we present Network-State-Adaptive QoS provision algorithm for 6LoWPAN, which adapts with the changing network state to ensure that QoS requirements are met even with the dynamic network states. It is a policy-based mechanism, which collaborates with the underlying routing protocol to satisfy the QoS requirements specified in the high level policies. It is simple in its implementation yet minimizes the degradation of the best effort traffic at a considerable level. Our implementation results show that our protocol adjusts well in dynamic 6LoWPAN environment where multiple services are competing for available limited resources.

Keywords—Internet of things; QoS provisioning; 6Lowpan; Policy-based QoS; IP-based Wireless Sensor Network; 6LoWPAN

I. INTRODUCTION

Wireless sensor networks (WSNs) consist of tiny sensor nodes with highly constrained computation, bandwidth and energy resources. WSN are integral part of IoT applications where sensing is necessary to observe the physical world. In most application scenarios, a large number of sensor nodes are deployed in the region of interest to collect and forward the data to a sink or data processing center. The data collection can be periodic, event-driven or query-based [1]. Seamless connectivity of WSNs with traditional IP networks is an essential requirement for realization of the IoT. Transmission of IPv6 over IEEE standard 802.15.4 (LoWPAN) [2] has given rise to the 6LoWPAN standard [3], which defines encapsulation and header compression for transmission of IPv6 over IEEE 802.15.4 networks. The standard enables us to connect these sensor networks with each other and with other IP-networks to maximize the utilization of information which is mainly associated with IP networks. This integration is pivotal to allow users to access the services in sensor networks as well as in the IP networks.

Though the existence of 6LoWPANs brings in great convenience for the users, it also presents novel underlying requirements and new technical challenges for the IoT research community. The main challenge is the dual nature of these networks, i.e., they are sensor networks as well as IP networks at the same time. Therefore, neither traditional IP-based QoS provisioning nor Wireless Sensor techniques are directly applicable to these networks. 6LoWPAN inherently posses dynamic topologies, limited processing power, small memory, and bandwidth constrained wavering capacity links. The introduction of modern real-time services concomitant to delay-agnostic services has further enhanced the complexity of the problem. 6LoWPAN nodes have limited resources to share between competing services, whereas the services require and expect high priority on the network with an objective of meeting high user expectations regarding reliability and quality. The available QoS provisioning algorithms are either inefficient or are embedded into routing protocols adding a high computation and communication load.

Lots of work has been done in QoS provisioning for sensor networks, e.g., [4] [5] as well as for IP networks [6][7]. However, the IP-enabled WSN domain is mostly an unexplored area.

Traditionally, to fulfill the QoS requirements, network managers attempt Hard-QoS or Soft-QoS mechanisms. In Hard-QoS provisioning, managers negotiate, reserve and hard-set capacity for various types of services (hard QoS). On the other hand, in the Soft-QoS case they merely prioritize data without reserving any "capacity setting". Hard QoS provisioning is not possible in the 6LoWPAN network because of their ad-hoc nature. Other IP-based frameworks like IP DiffServ and IntServ are extremely 'heavy' to be deployed directly on WSNs. Service differentiation could be a viable solution but it requires major adaptation to function reliably in the highly dynamic topologies.

In this paper, we propose a novel QoS provisioning mechanism for 6LoWPAN that provides soft QoS and adapts well with the changing network conditions. The solution can be used to implement user-defined high-level policies for services and is independent of the routing protocols. It can be integrated easily with the underlying routing protocols with minimal modifications. Our preliminary results show that our solution mitigates the degradation of best effort traffic and provides minimum QoS guarantees for applications.

The rest of the paper is organized as follows. In section II we outline the QoS provisioning requirements for IoT and

6LoWPAN. The details of our solution architecture are provided in section III followed by network state adaptive algorithm in IV. We present implementation details and preliminary evaluation results in sections V and VI respectively. A brief review of the state of the art is given in VII and paper is concluded in section VIII.

II. QoS Challenges for the IoT

Quality of service (QoS) provisioning is one of the key issues in 6LoWPAN networks' utility and penetration in the IoT market. Traditionally QoS refers to the measure of service quality from the network to the application. QoS is generally measured in terms of related parameters like available bandwidth, throughput, jitter, availability, delay, error rate, etc. In the case of traditional WSNs, application specific aspects such as data accuracy, aggregation delay, coverage, and network life are also considered as measures of QoS.

While QoS provisioning is an established domain in traditional networks, it still remains an open field when it comes to the IoT. In any IoT scenario, where WSNs and IP networks are integrated, a number of contrasting challenges have to be addressed to meet QoS requirements. While traditional networks mainly focus on end-to-end QoS provisioning, it is generally not the case with WSNs. WSNs are traditionally application-centric and therefore QoS parameters are determined not only by the network but also by application's requirements. The application may demand specific set of parameters, for example, data aggregation latency, accuracy of information, network life, coverage, minimum number of active sensors, fault tolerance threshold, etc. The network QoS provisioning is also influenced by the data delivery model being used. Event driven, query driven and continuous data delivery models affect the fault and delay tolerance, redundancy, user-interaction, and other QoS thresholds for sensor networks.

QoS provisioning in 6LoWPANs is different from just WSNs as well as just from IP networks because of the dual nature of these networks. On one hand, 6LoWPANs are IPv6 networks; while on the other hand, these are low power sensor networks with extremely limited resources. It means that we must provide lightweight IP-like solutions that can be deployed on resource constrained devices. Moreover, traditional networks run a diversity of applications as compared to WSNs where the network traditionally executes a single application in a cooperative fashion. However, because of the IP support, 6LoWPANs must support a variety of services as suggested in [8]. Running multiple applications on the highly resourced constrained devices makes QoS provisioning operations even more challenging. Followings are some of the challenges that must be addressed in order to provide a better QoS provisioning solution for 6LoWPAN.

Platform heterogeneity: In an environment where various type of networks are operating together, it is required that a QoS protocol works seamlessly on heterogeneous nodes as well as networks. Tackling such heterogeneity is one of the biggest challenges in realization of IoT. To cope up with the routing protocol heterogeneity, it is essential that the QoS provision mechanism is not embedded in a specific network protocol. Additionally it is important to have a mechanism, which adapts according to the application and network needs.

Dynamic network topology: Node failure and mobility are common phenomena in pervasive environments. Node failure has rather been considered as a 'normal event' for WSN as compared to IP networks where node failure is a rare event. The network topology in a wireless sensor network can change under various scenarios, e.g., a node or part of wireless sensor network moves out or die, joining of a new node, or some node(s) turn(s) to sleep mode to save energy. Such changes in topology badly affect the QoS provisioning. The QoS provisioning mechanism for IoT, therefore, should help network to discover new QoS-guaranteed route after topology changes.

Multiple Applications Support: In contrast to traditional WSNs where only one application is supported by the network, IP-WSNs may support multiple applications. These diverse applications may need to share the available network resources with different QoS requirements. While some applications generate periodic data, others could be driven by specified events. For instance, an application for event detection and target tracking needs real-time information from sensors. Therefore, the WSN must meet the delay and accuracy requirement during packet transmission. Furthermore, sensors for different kinds of physical variables, e.g., temperature, humidity, location, and speed, generate traffic flows with different characteristics which may need to be handled differently.

Resource constraints: WSN nodes are highly constrained in terms of battery, bandwidth, storage and communication capabilities. Specifically, efficient use of available energy conservation is critically important. It is therefore essential for a QoS mechanism to produce as less traffic overhead as possible in order to save energy and extend the network life.

Multiple Sinks: Traditionally WSNs are characterized with only one sink node but multiple gateways and sinks are also possible, especially where multiple applications are running on the network. In such cases QoS provisioning mechanism should be able to provide diversified parameters of service levels to support requirements from different sinks.

III. Soultion Architecture

Traditionally QoS support is application specific and is provided using the model in Figure 1.

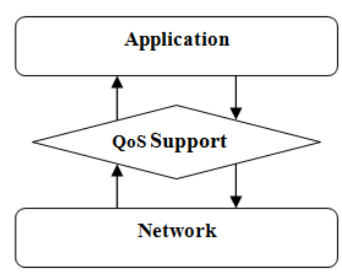

Fig. 1. A simple QoS model

Our solution, lowNETSAQ, is a lightweight policy-based framework which is loosely coupled with the underlying routing protocol and can work with any routing protocol with minimum tailoring. We have incorporated Policy-Based Management framework in our solution in order to allow user-defined configurations with respect to several applications, which may differ in network service requirements. While policy based network management has been in practice for decades, use of policies for QoS provisioning had gained special interest of researchers in recent years. High-level policies can be defined by the administrator to create a metric using path length, link quality, bandwidth, throughput and delay from source to destination node. The QoS is provided for diverse applications according the defined policies.

The mechanism operates between the underlying routing protocol and the application layer. QoS is separated from routing protocols to provide independence and flexibility in QoS mechanism. The QoS Protocol Stack is shown in Figure 2.

Fig. 2. QoS Implementation Stack

The QoS provisioning mechanism is lightweight and independent of routing protocol. But it can be integrated with most of the routing protocols. For obtaining the link information, the original routing table is customized. The mechanism incorporates additional metrics to the routing table data of the routing protocol. For instance, Figure 3 shows addition of two extra fields to routing table which hold information of QoS routing mechanism.

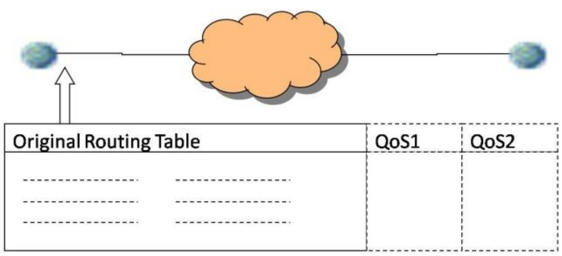

Fig. 3. Extra fields in routing table

The big picture of the architecture is given in Figure 4 and shows main components of the lowNETSAQ framework.

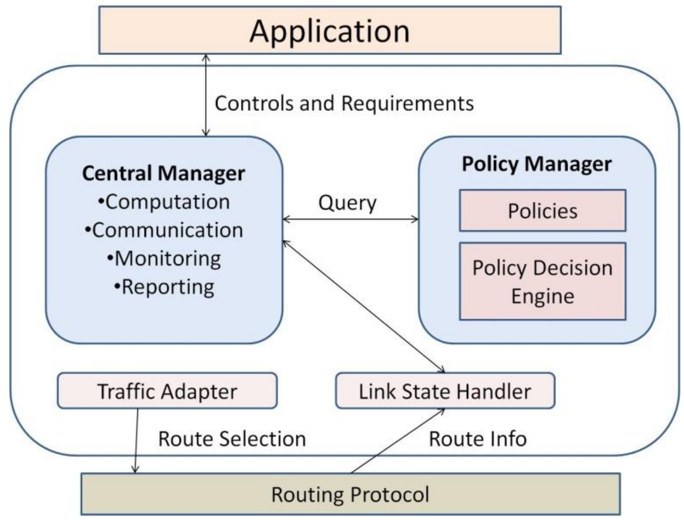

Fig. 4. Architecture of framework

A. Policy Manager

The policy manager can be used by the administrator to establish list of policies based on application requirements. A policy can be defined as a set of rules and decision strategy to be applied under specific circumstances to achieve a goal. These policies can be created using different parameters, such as, path length, link quality, bandwidth, throughput and delay from source to destination node, to provide diverse metrics for QoS provisioning. Policy-based approach enables the system to use the passive network monitoring information for active QoS provisioning. Policy decision engine is used to monitor the configurations using the central manager for deployment of the policy. The details of policy manager and policy decision engine design and implementation are subject of another paper and beyond the scope of this paper.

B. Central Manager

The central manager, in collaboration with other components, is responsible for monitoring the network state. In wireless sensor network, the network state is dynamic and unpredictable because of node mobility, node failure and battery exhaustion. A node of part of wireless sensor network moves out or even die, new node can join into the network or a node turn to sleep mode to save energy. All those situations make the network topology vary and the QoS mechanism must monitor these changes to provide an adaptable. Central manager corresponds with other components to perform such functions as monitoring link state, configuration of packet transmission metrics and reporting feedback to application.

C. Link State Handler

Link state handler gathers the route information of the network from the underlying routing protocol through routing table. This information is used by the QoS manager in route selection for a packet flow. As WSN state changes so dynamically, the solution must be able to adapt as network state change. lowNETSAQ makes sure that minimum QoS guarantees are met even when network state changes due to mobility, node failure or external interference.

D. Traffic Adapter

Traffic adapter is the core component of the system. It runs network state adaptive algorithm, which in collaboration with central engine makes route selection decisions. As WSN state changes so dynamically, the QoS provisioning mechanism needs to adapt with the network state changes. In order to meet end-to-end QoS requirements, the network will adapt to topology dynamically to guarantee minimum QoS requirements for either real-time or non-real-time applications.

IV. Network State Adaptive Algorithm

In a network, that provides services to multiple user applications, some applications may spell their QoS. We assume that, any application that starts has certain QoS requirements with minimum and maximum QoS bandwidth constraints. Our mechanism finds and uses the routing path which can meet the requested QoS specifications.

At the start of any application which specifies its requirements, the originator sends out route-discover message. When the metric values, bandwidth and delay are successfully obtained, route-discover-reply is sent to the originator.

Let's assume the bandwidth required by application is *Br*. For a given path *B1, B2, B3, …,Bn*, the maximum bandwidth available on the path is the minimum bandwidth available on a link on the path. It mean

$Bmax = min\{B1, B2, B3 \dots, Bn\}$ ... (1)

The application's QoS requirements are considered met if $Br <= Bmax$. otherwise an alternative path is to be found. During the path discovering and sending discover packet, the protocol updates the bandwidth field called *Bmax* in the routing table. Let *i* and *j* to be two positive integers (i.e. indexes of nodes) and i > j. When packet is received at each intermediate node, field *Bmax* is updated to *Bi* if condition *Bi* < *Bj*. Otherwise do nothing with the routing table.

Similarly, assume the delay required by application is *Dr*. The total delay that occurs of the path with *n* links/hops can be given by

$$Dtotal = D1 + D2 + D3 + \cdots + Dn$$

$$Dtotal = \sum_{i=1}^{n} D_i$$

Then we assert that

If *Dr* >= *Dtotal*, the path meets QoS requirement.

If *Dr* < *Dtotal*, then find another path.

During the path discovery phase, the protocol computes the sum of delay experienced at each node. It accumulates the *Dtotal* field of routing table when discover packet passes through each node. Let *i* to be the index of a node.

When route discovery packet reaches at each intermediate node, computing *Dtotal = Di + Dtotal'*. Where *Di* is delay experience on the current node, and *Dtotal'* is value of *Dtotal* field in routing table when packet is received on current node (i.e. *Dtotal* computed on last node).

For a single node in the network, delay is dependent on queue length and can be modeled as M/M/1 queue.

$$Q = \frac{1}{\mu - \lambda} \quad (2)$$

Where μ is processing rate and λ packet arrival rate. Processing rate μ is assumed as constant. In general, λ is equal to the sum of the average message flow rates of all paths traversing this node

$$\lambda = \sum_i \sum_j \gamma_{ij}$$

Here γ_{ij} is average message flow from node *i* to node *j*. To simplify the calculation, we assume all paths have same message flow γ. Let *m* to be the number of paths via a node. Then average arrival rate for a node is given by:

$$\lambda = \sum_m \gamma = m \cdot \gamma$$

To determine this we need gather information from the routing table or query on each node (how many source node pass this node corresponding to same number of path traverse it).

Equation (2) provides delay on a single node base on M/M/1 queue theory, and we can deduce the delay of a path.

$$D = \sum_{i \in path} Q = \sum_{i \in path} \frac{1}{\mu - \lambda}$$

After substitution we achieve

$$D = \sum_{i \in path} \frac{1}{\mu - \sum_i \sum_j \gamma_{ij}} \quad (3)$$

For finding out the route to meet the requirements in terms of *Bmax* and *Dtotal* given in equations (1) and (3) respectively, routing data and routing table information is used. Two additional columns, Band_width_for_route (*Br)* and Delay_for_route (*Dr)* are added to the routing table in 6LoWPAN. These columns are used for route selection based on requirements. To create and update these columns, Route Reply (RREP) message has been modified to get the link information. When a node sends out a RREP back to the originator, it adds these extra fields to the message. Figure 5 illustrates the flow of the protocol.

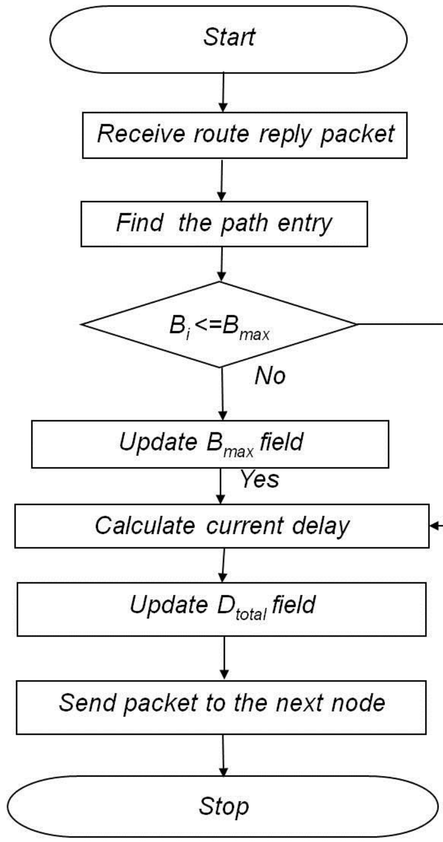

Fig. 5. Link State Updating Process

Every time an application specific data is to be sent, the objective is to find a path that meets QoS requirements of the application. Figure 6 outlines an algorithm for QoS provisioning.

1. Loop check each possible paths *Pi* in table
2. if Dr *(Pi)* >= D_{total}
3. if Br (Pi) <= B_{max}
4. transmit data using route *Pi*
5. else
6. find another path
7. End if
8. Else
9. find another path
10. End if
11. End loop

Fig. 6. Route Selection Algorithm

After examining all feasible paths if no path meets QoS requirements, then best effort delay and bandwidths are provided.

V. Implementation

We have implemented lowNETSAQ over Berkley 6LoWPAN stack [9] running on Advantics XM-1000 sensor nodes. The implementation consists of several modules based on the NesC and TinyOS frameworks. These modules cooperate with b6lowpan to provide routing with QoS support. Each component is lightweight and loosely coupled with others. Figure 7 shows the components and the interfaces between them.

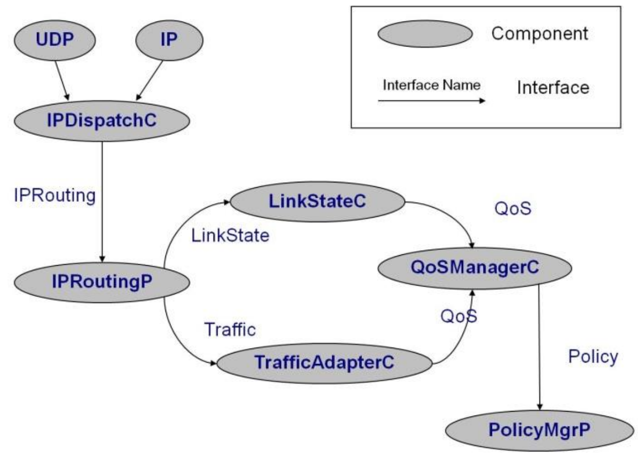

Fig. 7. Component Diagram

TrafficAdapterC:- A component for controlling route selection has been developed. This component contains TrafficAdapterP module which provides interface Traffic and uses interface QoS .TrafficAdapterP that cooperates with IPRoutingP and QoSManangerC. When sending a packet, TrafficAdapterP retrieves each route in routing table and queries QoSManangerC to check if it meets the QoS requirements. It returns the valid route to IPRoutingP after found a candidate route. LinkStateC component collects the network state information for QoS manager. The LinkStateP module has been implemented, which provides interface LinkState and uses infterfaces QoS, IP and IPAddress (see figure 8). The major job of this module is to maintain the network (links) state on each individual node. It calls QoS manager to calculate current network state via interface QoS. The calculation is based on the metrics collected from IP layer such as buffer size, number of neighbour and so on. When a route-discover message is received on a node, IPDispatchC invoke an event IP.recvfrom in the LinkStateP module. It decides to send the message back to origination node if message is not for this node, or update the link state information.

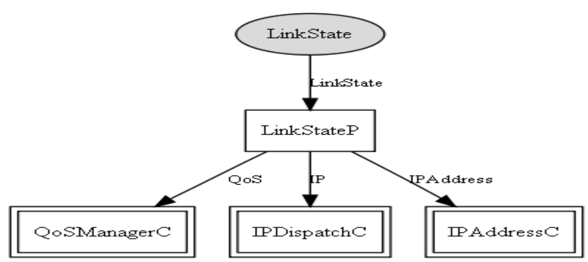

Fig. 8. Link State component

The QoSManagerC component is central to the mechanism. It does important computations and coordinates with other component. For the purpose of adopting QoS support for routing protocol, some modification has been made in IPRoutingC and IPDispatchC components of blip. The IPRoutingC component provides routing function. For decide an ideal route it needs to ask QoS manage to select route via TrafficC when sending packet at each time. It also implements a mechanism to send route discovery message periodically to gather network state information, and update routing table when receive route discovery message. This mechanism helps to maintain the link state information used for QoS manager. Another component that needs to be modified is IPDispatchC which manage send/receive packet, packet fragmentation and reassembly. Additional it need to capable to pass link information to LinkStateC component and forward route discovery message. Figure 9 shows the collaboration between each component.

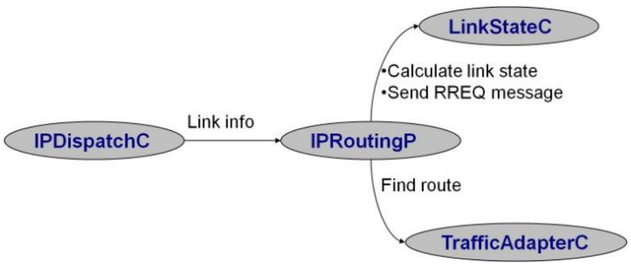

Fig. 9. Interaction of routing component

For the purpose of testing blip network and QoS provisioning mechanism, two applications have been developed in blip project which are UDPEcho and IPBaseStation. We have enhanced the code to support QoS provisioning.

VI. Evaluation

Our preliminary testbed comprised of 25 Advantics XM-1000 nodes with the transmission speed of 250kbps. The XM1000 is the new generation of mote modules, based on "TelosB" technical specifications, with upgraded 116Kb-EEPROM and 8Kb-RAM and integrated Temperature, Humidity and Light sensors. For examining the performance of QoS mechanism, the originator node sends message to base station on different data send rate. The larger data sending rate is selected in order to make congestion on the traffic. Sometimes turn off or move out of range the intermediate node to test the QoS mechanism to reroute the transmission due to dynamic network topology.

The evaluation results are obtained by comparing performance of best-effort traffic and QoS traffic (traffic with QoS support). Average delays, Average Throughput, Packet loss are the metrics used for evaluation.

Average delay is defined as the time escaped between transmitting a packet from originator and successfully receiving it at destination node. Figure 10 shows the average delay of both traffic increases sharply because of the contention of higher data rate. When data rate is 1 packet/s, there is no congestion in network, so the average delays of two traffics are similar. But after that the QoS traffic suffers less delay than best-effort traffic, because it redirect to another route when detecting the congestion or link quality decrease because of node mobility.

When sending rate is 8 packet/s, the delay of QoS traffic is prone to close to the value of best-effort traffic. This can be explained by the congestion that often occurs when send rate is large. As close to the bottleneck of traffic, the delay is keep in a static state that is almost equal to the time-out value.

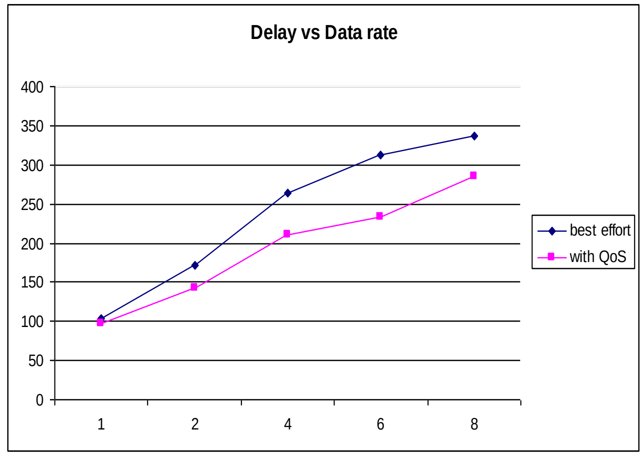

Fig. 10. Average delay vs. Data send rate

Fig. 11 presents the packet delivery ratio under different data sending rates. The experiment result shows the packet delivery probability is slightly improved by adopt the proposed QoS provisioning mechanism. But the network topology of test bed is small, and there are only two hops on each route. The packet delivery probability would be worse if there are more hops on the route, and the QoS traffic performs better than best-effort by choosing to use a QoS-guaranteed alternative route to transmit packets.

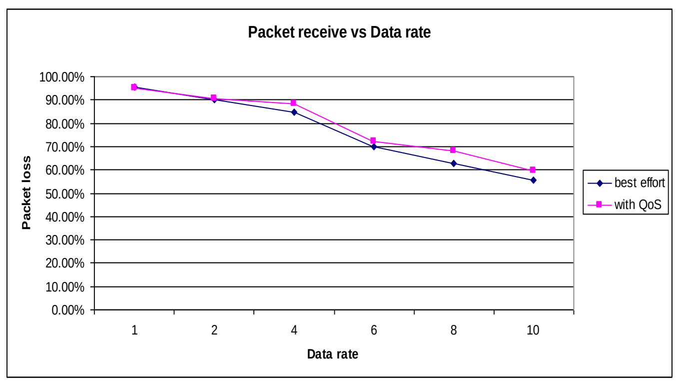

Fig. 11. Packet delivery ratio vs. Data rate

In order to test the max throughput of traffic, the size of packet is increased to 1 KB. This packet size is large enough to fill up the traffic capacity when data rate is faster. The throughput is calculated by counting how many packet is received divide by the time period, which gives the number of packet receive per second on the base station node. In QoS traffic, there is still degrading throughput of the node with larger sending rate. But the QoS provisioning mechanism works as expected, it does improve the performance of network.

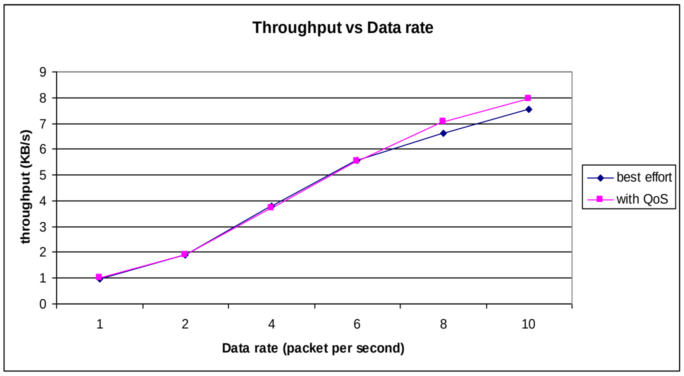

Fig. 12. Average Throughput vs. Data rate

From the comparison the performance in figures 10,11 and 12, it reveals that traffic flow with QoS provisioning mechanism performs better owing to route discovery, contention detecting, rerouting, and high-level policy control on sensor nodes.

VII. Related Work

Quality of service provisioning has been an important topic in recent years and a survey on research efforts in QoS in WSN is presented in [10].

Various efforts are carried out on multi-path approach for QoS provisioning. The work called SPEED [11] proposed a location-based routing protocol for soft end-to-end real-time guarantee for a desired delivery data speed in the network. This proposal does not take into consideration energy metric. An extension of SPEED is the MMSPEED - Multi-Path and Multi-SPEED Routing Protocol [12] which provides reliability and timeliness based on multi-path routing. The multiple paths are chosen depends on the required level of reliability and delivery speed. Another soft-QoS provisioning scheme is presented in [4], which considers multi-constrained QoS in WSN. This scheme utilizes the multiple paths between the sources and sink pairs for QoS provisioning. But as introducing IP infrastructure into WSN, those approaches are not applicable to provide end-to-end QoS provision.

Another effort for QoS provisioning protocol [13] focuses on reliability and energy-aware. This work is based on extension of 6lowpan ad hoc on-demand distance vector routing protocol (LOAD) proposed in [14]. The problem however is that LOAD has not been accepted as a generic routing protocol for 6lowpan. The QoS-aware protocol proposed in [15] implements a priority system that classifies the network traffic into real-time and non-real-time. The protocol is aim to find a least-cost, delay-constrained path for real-time data and maximize the throughput for non-real-time data. In [16] a service polling model base on two queues has been implemented to provide guaranteed QoS in WSN. This model also support for classify network traffic to real-time and non-real-time.

Another routing protocol is proposed in [17]which considers collisions and provides multipath routing to increase the network lifetime and throughput while decreasing latency.

In [18] forward error correction technique is used to provide fault recovery, balance the energy consumption over sensor nodes, and increase the reliability of data transmission.

The work in [19] proposed a QoS routing for time sensitive data delivery. However, this approach provides QoS guarantee at the cost of network life.

A delay guaranteed routing and MC protocol (DEGRAM) [20] proposes a joint-duty cycled MAC and routing protocol, which is based on contention free TDMA. The proposal, however, suffers from the inherent TDMA based MAC synchronization problem.

Source directed multipath routing [21] proposes unification of MAC and routing by using Wyner-Ziv lossy coding on application layer. This work targets hard QoS provisioning by reserved path, hop-by-hop QoS agreements, and admission control mechanisms.

However, those above approaches do not take into account the network state dynamic. The dynamic topology is universal phenomenon in wireless ad-hoc and sensor network. Hence, The QoS provisioning also need to be network state adaptive.

VIII. Conclusion

In this paper we presented a network state adaptive light-weight QoS provisioning mechanism for 6LoWPAN. The solution has been implemented on real test bed and preliminary results have been presented. The solution is loosely coupled with underlying protocol making it flexible to be used with any underlying protocol with minor modifications. The policy-based feature assures the scalability of system. In future works, we plan to test the performance on large test bed. Another important feature is to add more parameters to the QoS metrics.

References

[1] D.Chen and P.K. Varshney, "QoS support in Wireless Sensor Networks: A Survey" International Conference on Wireless Networks, Las Vegas, USA, June 2004.

[2] IEEE LoWPAN, 2003. Standard 802.15.4-2003, https://standards.ieee.org/about/get/802/802.15.html

[3] 6Lowpan working group, http://datatracker.ietf.org/wg/6lowpan/charter

[4] X. Huang and Y. Fang, "Multi-constrained Soft-QoS Provisioning in Wireless Sensor Networks", 3rd international conference on Quality of service in heterogeneous wired/wireless networks, Ontario, Canada, 2006

[5] E. Felemban, C. Lee and E. Ekici, "MMSPEED: multipath Multi-SPEED protocol for QoS guarantee of reliability and timeliness in wireless sensor networks", IEEE Transactions on Mobile Computing, Volume 5, Issue 6, pages 738-754, June, 2006

[6] Xiao H., Seah, W.K.G., Lo, A., Chua, K.C.: A Flexible Quality of Service Model for Mobile Ad-hoc Networks. *IEEE VTC*'00, Tokyo Japan, 2000.

[7] Jawhar, I., Wu, J.: Quality of Sevice Routing in Mobile Ad Hoc Networks. *Resource Management in Wireless Networking*, Kluwer, 2003.

[8] Ali Hammad Akbar, Ahmad Ali Iqbal, Ki-Hyung Kim: Binding Multiple Applications on Wireless Sensor Networks. GPC 2006: 250-258

[9] Berkley 6lowpan implantation, 2010. Available from: http://smote.cs.berkeley.edu:8000/tracenv/wiki/blip [Accessed May 10, 2015]

[10] Lin, F., Zhang, D., & Li, W. (2011). Research on quality of service in wireless sensor networks. In Software engineering and service science (ICSESS), 2011 IEEE 2nd international conference on, IEEE, pp. 312–315.

[11] Tian He, John A. Stankovic, Chenyang Lu, and Tarek Abdelzaher, “SPEED: A Stateless Protocol for Real-Time Communication in Sensor Networks”, *23rd International Conference on Distributed Computing Systems* (ICDCS '03). IEEE Computer Society, Washington, DC, USA, 2003.

[12] E.Felemban, C. Lee and E. Ekici, “MMSPEED: multipath Multi-SPEED protocol for QoS guarantee of reliability and timeliness in wireless sensor networks” IEEE Transactions on Mobile Computing, vol. 5. No.6. pp: 738-754, 2006. DOI: 10.1109/TMC.2006.79

[13] C. Weston, P. T. Tu, B. Baiteli and S. Y. Ma, “Energy-aware and QoS Routing in 6LoWPAN Mesh Networks”, ZRDC conference, Zambia, April 30, 2007.

[14] K. Kim, S. D. Park, G. Montenego, S. Yoo and N. Kushalnagar, “6LoWPAN Ad Hoc On-Demand Distance Vector Routing (LOAD)”, IETF Internet Draft, March 2006.

[15] K. Akkaya and M. Younis, “Energy and QoS aware Routing in Wireless Sensor Networks” Cluster Computing Volume 8 , Issue 2-3 (July 2005) Pages: 179 – 188

[16] M. Y Aalsalem, M. Iftikhar, J. Taheri and A. Y. Zomaya, “On the Provisioning of Guaranteed QoS in Wireless Sensor Networks through Limited Service Polling Models”, 2006

[17] Y. Chen, N. Nasser, T. El Salti and H. Zhang, “A multipath QoS routing protocol in wireless sensor networks,” International Journal of Sensor Networks, Vol. 7, Issue. 4, pp: 207–216. 2010. DOI: 10.1504/IJSNET.2010.033204

[18] J. Ben-Othman and B. Yahya, “Energy efficient and QoS based routing protocol for wireless sensor networks”, Journal of Parallel and Distributed Computing, Vol. 70, issue. 8: pp. 849–857.2010. doi:10.1016/j.jpdc.2010.02.010

[19] T. Houngbadji, and S. Pierre, “QoSNET: an integrated QoS network for routing protocols in large scale wireless sensor networks,” Computer Communications, vol. 33, issue 11: pp. 1334–1342. 2010.DOI: 10.1016/j.comcom.2010.03.017

[20] C. Shanti and A. Sahoo, “Dgram: A delay guaranteed routing and mac protocol for wireless sensor networks,” IEEE Transactions on Mobile Computing, Vol. 9 No. 10, 1407–1423.2010.

[21] G. Shah, W. Liang and O. Akan9,“Cross-layer framework for qos support in wireless multimedia sensor networks”, IEEE / ACM Transactions on Multimedia, Vol. 14. No.5, 1442–1455. 2012.

Formal Verification of a Secure Model for Building E-Learning Systems

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***Abstract*—Internet is considered as common medium for E-learning to connect several parties with each other (instructors and students) as they are supposed to be far away from each other. Both wired and wireless networks are used in this learning environment to facilitate mobile access to educational systems. This learning environment requires a secure connection and data exchange. An E-learning model was implemented and evaluated by conducting student's experiments. Before the approach is deployed in the real world a formal verification for the model is completed which shows that unreachability case does not exist. The model in this paper which is concentrated on the security of e-content has successfully validated the model using SPIN Model Checker where no errors were found.**

Keywords—Formal verification; SPIN Model Checking; E-content; E-protection; Encryption and Decryption; Security of e-content

I. INTRODUCTION

A formal verification for a secure e-learning system model was designed for implementation by computer centers in universities. Figure 1 indicates a secure model for building e-learning systems [1]. This study formally verifies the suggested model, which presents a wireless system that provides university users with remote access to the database files of students. A new security system is proposed to verify if e-learning application environment has weaknesses and to assess data cryptography at rest and in transit. [1] proposed a system that could validate user input for malicious data. In their proposed system, access switches connect all PCs, and a core switch then connects all wireless devices to the access point and secures them using open virtual private network (openVPN) on the client side with a MAC address. The application servers of students located in the computer center are connected to the core switch. This setup adds to a secure connection. The firewall guards the core switch and the entire network. The university is connected remotely using OpenVPN and Pretty Good Privacy (PGP).

The study applies a SPIN model checker to verify the proposed model. The model is presented as a Unified Modelling Language (UML) state diagram using the ArgoUML CASE tool.

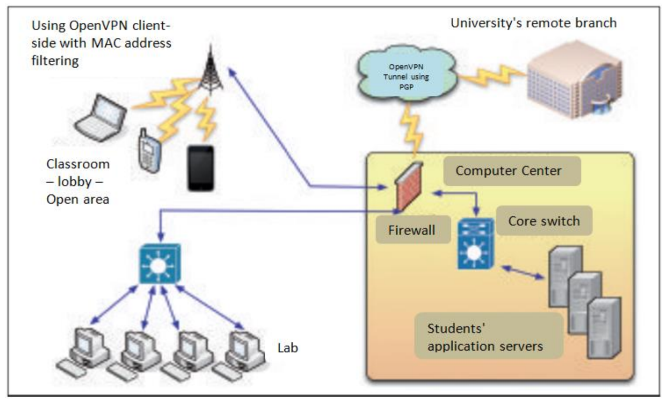

Fig. 1. Secure e-Learning System Model

II. RELATED WORK

A. Formal Verification

A significant area in formal methods is the concept of formal verification. Formal methods include mathematical techniques and tools that are applied for models, specifications, and verification of systems [2]. These factors focus on the formal behavior description of systems, and specifications reflect the degrees of these systems.

In formal verification, the state space of the system utilizes model checkers for determining the specification properties [3]. If these properties are valid, model checkers will return empty files. However, errors will result in a file which is generated by SPIN and called the *TRAIL* file (i.e., output file of the SPIN model checker) or will generate a counter example (i.e., output file of the SMV model checker) to present the process of the violation. Thus, the model checker could present as a series of model states that contain model variables and their values at that state, which aggravate the violations [4].

To check the model system, a finite state machine has to be verified. SPIN verification aims to check violations of safety and liveness factors [5]. Safety properties should prevent errors from occurring. For example, the model should not be exposed to invariants and deadlocks, which would prevent the achievement of possible states.

SPIN inspects a safety property by searching for traces that could direct to an “undesired” element. The lack of trace then satisfies the property [3]. Therefore, the SPIN model checker evaluates assertions that can be utilized between any two statements in the state space [6]. When the model checker determines a calculation that can cause false assertion, the program encounters an error or the assertion is unable to express a correct property [6]. The evaluation is simulated with a true or false expression for a specific statement. If a statement progresses correctly, then the model checker will proceed to the next statement. However, if the statement is unable to progress correctly, then the program will terminate by indicating a trail showing the number of these errors [7].

Linear Tree Logic (LTL) can be applied in several cases to model the time sequence. These models can be translated by SPIN into a never claim, which is then executed together with the finite automaton that represents the Process or Protocol Meta Language (PROMELA) program. LTL may be used to verify certain properties of the system, such as safety, liveliness, and lack of deadlocks [8].

The application of SPIN to formal verification has been commonly used in evaluating security models. For instance, [9] analyzed the security of an approach using behavior-based anti-phishing, and [10] used the SPIN model checker for verifying the security of an anti-phishing model and they found no deadlocks on that model.

This paper evaluates the approach’s efficiency by means of formal methods. This research verifies the E-learning model presented in Figure 2 in a formal technique. The verification helps to check whether the model is viable (i.e. un-reachability case does not exist) so as to apply it in the real world. The E-learning model is verified in a formal manner using SPIN model checker. The approach in this paper uses UML state diagram to specify the state model and the state transitions based on the diagram. This UML diagram is translated into PROMELA language code (i.e. the input language of SPIN model checker) so it can be analyzed by SPIN.

B. *Secure e-Learning Systems*

Researchers have presented the security issues and weaknesses of e-learning systems from various perspectives. [11] elaborated that the security issues of an e-learning schema use four pillars that should be positioned to enhance overall security. These pillars boost e-learning security, present e-learning security policies and procedures, apply e-learning security counter measures, and scrutinize the e-learning security countermeasures.

On the other hand; [12] introduced the security features of e-learning authentication. Using web application for security requires utilizing the SKiP method to provide the same features of SSL. Moreover, using RIPEMD-160 hash function is suggested to provide security and authentication whereas [13] argued that Information Security Management (ISM) is essential to safeguarding the security of the e-learning environment. Combining ISM and information security technology could assure a better security implementation of the e-learning system. This step assures improved results of the successful implementation of security. [1] proposed a model that could deal with securing the e-content of the e-learning system and improve mobile access to several learning systems.

III. MATERIALS AND METHODS

The verification methodology used in this research was successfully used in previous papers by [9] and [10] where this research focuses mainly on the formal verification of the proposed e-learning model using SPIN model checker. In this case, SPIN could be used to verify the model against vulnerabilities based on the system’s mechanism that’s shown in figure 2. Each part of the model is considered as a different process. These processes are recognized in PROMELA (Process or Protocol Meta Language). PROMELA reads the behavior of the processes that’s described in the state diagram in figure 2. These model entities communicate with each other using some global channels. Accordingly, the E-learning model is designed in UML (Unified Modeling Language) state diagram using a case tool called ArgoUML. The generated UML model is then mapped into a PROMELA code using a tool called Hugo/RT which can capture the properties of the model and save it as a PROMELA program. For formal verification process the generated code is combined with some LTL properties that will be used for verifying the timing of the model responses as illustrated in Figure 2.

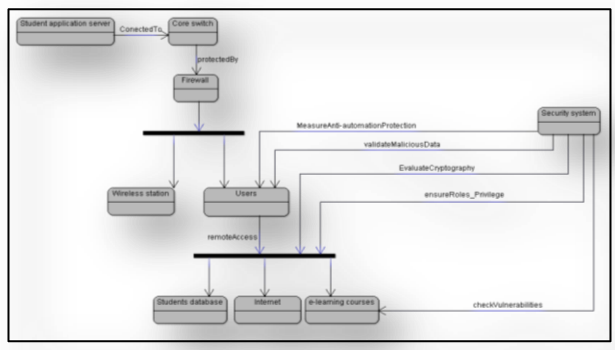

Fig. 2. E-learning Model State Diagram

As stated in Figure 2 student application server is connected to a core switch which is protected by a firewall for the wireless station as well as the users. The security system can work for multiple tasks, i.e. the measurement of the anti-automation and the validation of malicious data of users as well as ensuring the roles and privileges for the database, the internet and the e-learning courses and checking the vulnerabilities for these courses.

IV. RESULTS AND DISCUSSION

The PROMELA code for the e-learning model is translated and written to fit the SPIN model checker. The code is written as follows:

```
proctype E-learning (){
printf("initiating E-learning  Process...\n");
DisplayMenuState:
UserInterface!DISPLAY_Options->
```

```
printf("E-learning  Process: connected to Core
switch...\n");
printf("E-learning  Process: Protected by
Firewall...\n");
goto Securitysystem;
printf("initiating E-remoteaccess  Process...\n");
UserInterface!security systems->
do:: MeasureAnti-automationProtection
   :: validateMaliciousData
printf("E-learning  Process:
AccessToDdatabase...\n");
printf("E-learning  Process: AccessToInternet...\n");
printf("E-learning  Process: AccessToE-
learningCourses...\n");
Od::
goto Securitysystem;
do:: EvaluateCryptography
   :: ensureRoles_Privilege
printf("E-learning  Process:
AccessToDdatabase...\n");
printf("E-learning  Process: AccessToInternet...\n");
printf("E-learning  Process: AccessToE-
learningCourses...\n");
od::
goto Securitysystem;
do:: checkVulnerabilities
printf("E-learning  Process: AccessToE-
learningCourses...\n
od::

  ...

  }
```

After the PROMELA code is written for the model, SPIN verification checks for deadlocks and unexecuted codes in the e-learning model. Figure 3 shows that SPIN does not show any "invalid end state," given that no deadlock is observed in the model. Moreover, the result shows no error and unexecuted codes, and all processes have zero unreached states.

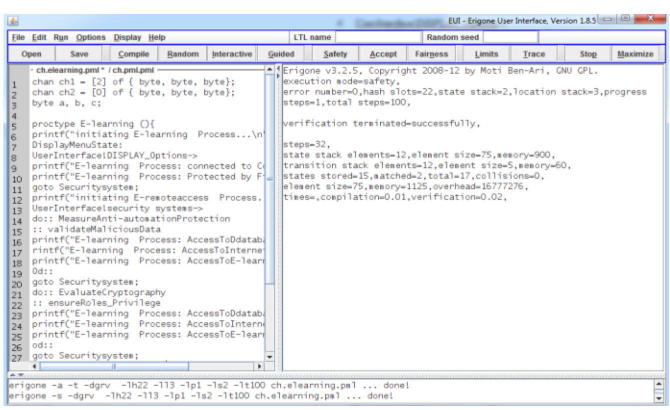

Fig. 3. SPIN Model Checker Result

The states *initiating E-remoteaccess*, *AccessToDatabase*, *AccessToInternet*, and *AccessToE-learningCourses* after *SecuritySystem* have multiple entry points. Figure 3 shows the verification of the properties of these states with the LTL properties. The results indicate that the proposed e-learning model passes these properties during checking. Therefore, the SPIN model checker can validate the model as indicated by the absence of deadlocks or unreachable states.

V. Conclusion and Future Work

This research met the objectives of the study by plotting the model and formally evaluating the proposed e-learning model. Further, the study effectively coded the model using PROMELA and validated the program using the SPIN model checker. The method checked for deadlocks and unreachable states, which did not emerge from the model. Future research could look into proposing another model checker, such as the Symbolic Model Verifier, which could be applied to gain clear results on the veracity of the behavior of the e-learning model.

Acknowledgment

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References

[1] Shadi R Masadeh, Nedal Turab, Farhan Obisat, 2012. *A secure model for building e-learning systems. Network Security*, Volume 2012, Issue 1, January 2012, Pages 17-20.

[2] Wing J. M., "*A specifier's introduction to formal methods*," Computer, vol. 23, no. 9, pp. 8–23, 1990.

[3]] M. Machin, F. Dufossé, J. Guiochet, D. Powell, M. Roy and H. Waeselynck, "Model-Checking and Game theory for Synthesis of Safety Rules," *2015 IEEE 16th International Symposium on High Assurance Systems Engineering*, Daytona Beach Shores, FL, 2015, pp. 36-43.

[4] Matthew L. Bolton, Noelia Jimenez, Marinus M. van Paassen and Maite Trujillo "*Automatically Generating Specification Properties From Task Models for the Formal Verification of Human–Automation Interaction*" IEEE Transactions On Human-Machine Systems, vol. 44, No. 5, October 2014R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.

[5] Manu S. Hegde, Jnanamurthy HK and Sanjay Singh, "*Modelling And Verification Of Extensible Authentication Protocol Using* SPIN *Model Checker*" International Journal of Network Security & Its Applications (IJNSA), Vol.4, No.6, November 2012.

[6] Hegde, M. S., Jnanamurthy, H. K., & Singh, S. (2012). *Modelling and Verification of Extensible Authentication Protocol using SPIN Model Checker*.International Journal of Network Security & Its Applications (IJNSA), 4(6), 81-98.

[7] Samanta, R., Deshmukh, J. V., and Emerson, E. A. (2008, November). *Automatic generation of local repairs for boolean programs. In Formal Methods in Computer-Aided Design*, 2008. FMCAD'08 (pp. 1-10). IEEE.

[8] Michael Huth and Mark Ryan, (2007) Logic in Computer Science, Cambridge.Philippsohn S. "*Trends In Cybercrime — An Overview Of Current Financial Crimes On The Internet*", in Computers & Security, 20 (1), 2001 pp. 53-69.

[9] Abdullah M. Alnajim, "An Evaluation of A Country Based AntiPhishing Approach Using Formal Methods" International Journal of Computer Science & Engineering Technology (IJCSET) ISSN : 2229-3345 Vol. 6 No. 07 Jul 2015.

[10] Abdullah M. Alnajim and Hazim S. AlRawashdeh, "Verifying an Anti-Phishing Model Using Formal Methods" International Journal of Soft Computing Year: 2016, Volume: 11, Issue: 2, Page No.: 76-82.

[11] Kritzinger, E; von Solms, SH. 'E-learning: Incorporating Information Security Governance'. 2006. Accessed Dec 2011. *www.informingscience*.org/proceedings/InSITE2006/ IISITKrit157.pdf.

[12] A. Jalal and Mian Ahmad Zeb. *'Security Enhancement for E-Learning* Portal'. IJCSNS International Journal of Computer Science and Network Security, Vol.8 No.3, 2008.

[13] Najwa Hayaati, Mohd Alwi, Ip-Shing Fan. *'E-Learning and Information Security Management'*. International Journal of Digital Society (IJDS), Volume 1, Issue 2, 2010.

Performance Evaluation of Support Vector Regression Models for Survival Analysis: A Simulation Study

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***Abstract*—Desirable features of support vector regression (SVR) models have led to researchers extending them to survival problems. In current paper we evaluate and compare performance of different SVR models and the Cox model using simulated and real data sets with different characteristics. Several SVR models are applied: 1) SVR with only regression constraints (standard SVR); 2) SVR with regression and ranking constraints; 3) SVR with positivity constraints; and 4) L1-SVR. Also, a SVR model based on mean residual life is proposed.**

Our findings from evaluation of real data sets indicate that for data sets with high censoring rate and high number of features, SVR model significantly outperforms the Cox model. Simulated data sets also show similar results. For some real data sets L1-SVR has a significantly degraded performance in comparison to the standard SVR. Performance of other SVR models is not substantially different from the standard SVR with the real data sets. Nevertheless, the results of simulated data sets show that standard SVR slightly outperforms SVR with regression and ranking constraints.

Keywords—support vector machines; support vector regression; survival analysis; simulation study; Cox model; mean residual life

I. Introduction

Survival analysis is applied in different fields, such as medicine, public health, biology, epidemiology, engineering, economics, and demography. In survival studies within the medical field, patients are followed over the length of a predefined period. Those patients which experience an event of interest (failure) during the follow-up period are considered as complete (uncensored) observations. An event of interest is defined as some individual occurrence or experience such as death, disease incidence, relapse from remission, etc. The patient, whose exact time of event is not known but is known to occur in a certain period of time, is considered as censored. Right censoring is the most common form of censoring which is focused on in this study. If a patient is right censored at a given time, he has not experienced the event by that time and the event of interest will occur after wards. For example if the death is considered as the event of interest then the patients who survive the entire follow-up period are considered as right censored [1].

The traditional models such as the Cox proportional hazard model and the accelerated failure-time model are applied in statistical literature for survival prediction [2, 3]. The most common survival model is the Cox proportional hazards regression. This model requires the proportional hazard assumption that is not always realistic. Also Cox is not able to model the nonlinear relations. Some other models such as artificial neural networks (ANN) and support vector machines (SVM) are applied for overcoming these problems [4-6]. SVM models are based on the statistical learning theory and have some beneficial features. They are able to model nonlinear relationships between variables using the kernels. Also they result in globally optimal solutions by solving a convex optimization problem, while contemporary models such as artificial neural networks deal with problems of local minima [7].

SVM first was proposed for solving classification problems [8]. Later, these models were extended to be applicable in regression problems [9]. Support Vector Regression (SVR) has been extensively applied in the literatures for response prediction [10-13]. However, there are few studies which use SVR for survival analysis. This is in part due to the response variable (survival time) in survival analysis including censored observations that the traditional SVR is not able to model.

However, the desirable features of SVR have led researchers to extend them to be applicable in survival problems.

Yijun et al. [14] considered the survival time as a categorical variable and used the support vector classification model for survival analysis. The SVR model for survival analysis is proposed by Shivaswamy et al. [7]. The authors investigated performance of some competing SVR models for real data sets with different censoring percentages. Ding [15] also has discussed possible application of SVM in survival analysis. They applied SVR model with different kernels on some real data sets. Khan and Zubek [16] compared SVR with Cox for five real data sets. Van Belle et al. [17, 18] proposed a SVR approach making use of ranking and regression constraints for right censored data. The authors compared performances of SVR and Cox models for both clinical and micro-array datasets. Also, they discussed a modified SVR model for other types of censorships in [6]. In another study, a new survival modeling technique based on least-squares SVR was proposed. The proposed model was compared with classical techniques on a breast cancer data set [19]. Du and Dua [20] applied SVR with two feature selection methods namely individual feature selection and feature subset forward selection and discussed their effect on performance of Cox and SVR on breast cancer data sets.

A data set has characteristics such as: censoring percentage, number of features and training sample size. To the best of our knowledge, there is no previous survival study which uses simulated data with different characteristics for evaluating and comparing performance of Cox and SVR models. The aim of this study is evaluating and comparing performance of various SVR models and Cox for survival analysis using simulated and real clinical data sets. To this end, different SVR models are applied: 1) SVR with only regression constraints; 2) SVR with regression and ranking constraints; 3) SVR with positivity constraints; 4) L1-SVR. Also, a new SVR model based on mean residual lifetime (MRL) is proposed.

The rest of this paper is organized is follows. SVR models for censored data are explained in section 2. Section 3 gives three performance measures which are used for comparing the models. In section 4 three real data sets are described. Section 5 explains the simulation method which is used to make clinical data sets with different characteristics. In section 6, the results of implemented analysis on artificial data sets as well as real data sets are presented. Finally, discussion is given in Section 7 and Section 8 is conclusion.

II. SVR MODELS

In this section, first, the standard SVR model is described for censored data. Second, a new SVR model is proposed and other SVR models and Cox regression are explained.

A. Standard SVR for survival analysis

SVM models are able to incorporate nonlinearity relations by different kernels. SVM do not use standard statistical approaches for estimation of model parameters. In these models the empirical risk of misranking two instances with regard to their event time, is minimized. We used some notations throughout the current text. x_i denotes a d-dimensional vector of independent variables, y_i is the corresponding survival and δ_i is censorship status. δ_i is 1, if an event has occurred, and δ_i is 0, if the observation is right censored. The prognostic index, i.e. the prediction of the model in SVR, is formulated as:

$$u = w^T \varphi(x) + b \tag{1}$$

In (1), w denotes the weight vector, $\varphi(x)$ denotes a transformation of the variables and b is a constant. To estimate the parameters, SVR is formulated as an optimization problem and a loss function is minimized subject to some constraints [6]. Shivaswamy et al. [7] proposed a modified algorithm for employing SVR to survival problems. This algorithm modifies the constraints of standard SVR. In this paper, standard survival SVR, is called SSVR and is formulated as:

SSVR:

$$\min_{w,b,\epsilon,\epsilon^*} \quad \frac{1}{2} w^T w + \gamma \sum_{i=1}^{n} (\epsilon_i + \epsilon_i^*) \tag{2}$$

$$\textit{subject to } (\forall i = 1, \dots, n): \begin{cases} w^T \varphi(x_i) + b \geq y_i - \epsilon_i, \\ -\delta_i (w^T \varphi(x_i) + b) \geq -\delta_i y_i - \epsilon_i^*, \\ \epsilon_i \geq 0, \\ \epsilon_i^* \geq 0. \end{cases}$$

In (2) n is sample size and the parameter γ is a positive regularization constant. ϵ_i and ϵ_i^* are slack variables and allow the errors in the prediction. The large values of slack variables are penalized by the loss function. The prognostic index, the prediction of the model, for a new point x^* is computed as:

$$\hat{u}(x^*) = \sum_{i} (\alpha_i - \delta_i \alpha_i^*) \varphi(x_i)^T \varphi(x^*) + b, \tag{3}$$

Where α_i and α_i^* are the Lagrange multipliers. $\varphi(x_i)^T \varphi(x_j)$ is formulated as a positive definite kernel:

$$k(x_i, x_j) = \varphi(x_i)^T \varphi(x_j), \tag{4}$$

Kernels often used for survival data are: linear, polynomial, RBF and clinical [21]. The linear kernel is formulated as:

$$k(x, z) = x^T z \tag{5}$$

Linear kernel was employed for all experiments in this paper.

B. A new SVR model using MRL function

The survival SVR model discussed in previous section uses a one-sided loss function for errors arising from prediction of censored observations. This loss function penalizes the model only when the censored observations are predicted smaller than their censoring time. A new SVR model is proposed which uses a two-sided loss function.

This model assumes that the event time for a censored observation, is equal to sum of its censoring time and the MRL. For individuals of age x, MRL measures their expected remaining lifetime [1] and is calculated using the following formula:

$$\boxed{MRL(x) = \frac{\int_x^{\infty} S(t)dt}{S(x)}} \tag{6}$$

where S(x) is survival function. A standard estimator of the survival function is Kaplan–Meier estimator which is used in current study. Therefore, the model is also penalized when censored observations are predicted greater than sum of censoring time and the MRL. This model is called SSVR-MRL in this paper and is formulated as follows.

SSVR-MRL:

$$\min_{w,b,\epsilon,\epsilon^*,\xi} \quad \frac{1}{2}w^T w + \gamma\sum_{i=1}^{n}(\epsilon_i + \epsilon_i^*) + \mu\sum_{i=1}^{n}\xi_i, \qquad (7)$$

$subject\ to$ $(\forall i = 1, \ldots, n)$:

$$\begin{cases} w^T\varphi(x_i) + b \geq y_i - \epsilon_i, \\ -\delta_i(w^T\varphi(x_i) + b) \geq -\delta_i y_i - \epsilon_i^*, \\ (\delta_i - 1)(w^T\varphi(x_i) + b) \geq (\delta_i - 1)(y_i + MRL_i) \\ \epsilon_i \geq 0, \\ \epsilon_i^* \geq 0, \\ \xi_i \geq 0, \end{cases}$$

The prognostic index, for a new point x^* is found as:

$$\hat{u}(x^*) = \sum_{i=1}^{n}(\alpha_i - \delta_i\alpha_i^* + (\delta_i - 1)\beta_i)\varphi(x_i)^T\varphi(x^*) + b, \qquad (8)$$

Where α_i, α_i^* and β_i are the Lagrange multipliers. For more information, please refer to [18].

C. Linear survival-SVR model with positivity constraints

This model is used for feature selection. In this model, a constraint is added the SSVR model to ensure positivity of weights [17].

Feature selection is included in this model by restricting the weights w to accept positive values. In this method, a preprocessing step on the dataset is required before training the model. Suppose x^p presents the p^{th} feature of input data. The concordance between each x^p and the event time is calculated, and each x^p with a concordance less than 0.5 is changed to $-x^p$. This model is called SSVRP in this paper. After modifying the data set, model is trained on data set. The estimation is obtained by solving the following optimization problem:

SSVRP:

$$\min_{w,b,\epsilon,\epsilon^*} \quad \frac{1}{2}w^T w + \gamma\sum_{i=1}^{n}(\epsilon_i + \epsilon_i^*), \qquad (9)$$

subject to $(\forall i = 1, \ldots, n, \forall p = 1, \ldots, d)$:

$$\begin{cases} w^T x_i + b \geq y_i - \epsilon_i, \\ -\delta_i(w^T x_i + b) \geq -\delta_i y_i - \epsilon_i^*, \\ w_p \geq 0, \\ \epsilon_i \geq 0, \\ \epsilon_i^* \geq 0. \end{cases}$$

This constraint leads to the estimated weights be close to zero for irrelevant variables and be higher for relevant variables.

D. L1-SVR method

L1-SVR is another SVR model that is used for feature selection. In this model, the L1 penalty, $\sum_{i=1}^{d}|w_i|$ is used instead of the term $w^T w$. This model results in sparse solutions. Therefore, it selects fewer features than standard SVR [6]. In this paper, L1-SVR for survival analysis is called L1-SSVR.

E. A survival-SVR using ranking and regression constraints

Van Belle et al. [17, 18] proposed an SVR approach which makes use of ranking and regression constraints. This model is called SSVR2 in this paper. The standard SVR method (SSVR) includes only the regression constraints but SSVR2 includes the both regression and ranking constraints. In this method, the observations are arranged according to their event or censoring times. Then comparable pairs of observations are identified. A data pair is defined to be comparable whenever the order of their event times is known. For example, if patient *A* is censored in time *a* and patient *B* is uncensored with the related event occurring at time *b* (*a*<*b*), they are not comparable as it is not known that which has occurred earlier.

Since the event time for a censored observation is not known, a data pair is comparable if both observations are uncensored, or only one of them is uncensored with the censoring time of the other observation being later than event time of the uncensored observation.

The SVR method with ranking constraints involves a penalization for each comparable pair of observations for which the order in the prediction of model (prognostic index) differs from the observed order. The number of comparisons is reduced by comparing each observation *i* with the comparable neighbor with the largest survival time smaller than y_i, which will be indicated with $y_{j(i)}$. This model for censored data is formulated as:

$$\min_{w,b,\epsilon,\epsilon^*,\xi} \quad \frac{1}{2}w^T w + \gamma\sum_{i=1}^{n}(\epsilon_i + \epsilon_i^*) + \mu\sum_{i=1}^{n}\xi_i, \qquad (10)$$

subject to $(\forall i = 1, \ldots, n)$:

$$\begin{cases} w^T\varphi(x_i) + b \geq y_i - \epsilon_i, \\ -\delta_i(w^T\varphi(x_i) + b) \geq -\delta_i y_i - \epsilon_i^*, \\ w^T\left(\varphi(x_i) - \varphi\left(x_{j(i)}\right)\right) \geq y_i - y_{j(i)} - \xi_i \\ \epsilon_i \geq 0, \\ \epsilon_i^* \geq 0, \\ \xi_i \geq 0, \end{cases}$$

The parameters γ, μ in SVR models were tuned using the three-fold cross-validation criterion. Different SVR models were used for survival analysis using artificial and real data sets.

The prognostic index, for a new point x^* is computed as:

$$\hat{u}(x^*) = \sum_{i=1}^{n}\left(\alpha_i\left(\varphi(x_i) - \varphi\left(x_{j(i)}\right)\right)^T + (\beta_i - \delta_i\beta_i^*)\varphi(x_i)^T\right)\varphi(x^*) + b, \qquad (11)$$

Where α_i, β_i and β_i^* are the Lagrange multipliers [18].

F. Cox proportional hazard (PH) model

The Cox PH model is formulated as:

$$h(x,t) = h_0(t)exp(w^T x) \quad (12)$$

$h(x,t)$ denotes the hazard rate, $h_0(t)$ is a baseline hazard rate, *x* is a specific feature vector and *t* is the time at which the hazard is to be calculated. The hazard rate is the instantaneous risk to occur the event now, knowing that the event did not happen before. The Cox PH model is based on the proportional hazards assumption. This assumption presumes that the ratio of hazard rates for each two individuals in study is constant. The hazard of an observation with covariates x_i is associated to $w^T x_i$. The parameters *w* are estimated by maximizing the partial likelihood function [1, 3]. Cox model was used for comparison with SVR models.

III. Performance Measures

Three performance measures were used for performance evaluation of survival models [17, 18, 21].

The researchers are usually interested in groups of patients with higher or lower risk profiles. Therefore, the concordance index (c-index) is used as a first performance measure to assess the concordance between the model results and the observed survival. For the second measure, patients are divided into two risk groups according to median prognostic index. The median prognostic index is used as threshold to identify the two groups. The second measure is the logrank test χ^2 statistic that measures the difference in survival between the two groups. To obtain a third measure, first the estimated prognostic indexes are normalized. Then a univariate Cox model is fitted to the normalized prognostic indexes. The estimated hazard ratio for this model is reported as the third measure. For all used performance measures, higher measures indicate better performance.

IV. Real Data Sets

The first data set concerns a historical cohort study which was performed on 197 heart attack patients, who visited the hospitals of Bushehr port, in South of Iran, from April 1997 to April 2001. Inclusion criteria were as follows: (i) the patient must be living in Bushehr, and (ii) the patient has not had a heart attack previously. In this experiment (HA), the event is death. The patient status and event time were attained by visiting the patients. The data set contains information on sex, age, cholesterol, LDL, HDL, systolic blood pressure and diastolic blood pressure.

We also used two publicly available data sets[1] for four other experiments. The first data set is from the Mayo Clinic trial in primary biliary cirrhosis (PBC) of the liver conducted between 1974 and 1984 [22]. This data set contains 312 PBC patients that have participated in the randomized trial. A total of 276 patients remain after removing missing values. In a first experiment (PD), the event is death while in a second experiment (PT) the event is transplantation. The variables in this data set are as follows: age, sex, stage, treatment, alkaline phosphatase, aspartate aminotransferase, albumin, bilirubin, cholesterol, triglycerides, urine copper, edema, platelet count, presence of ascites, presence of hepatomegaly or enlarged liver, standardized blood clotting time and blood vessel malformations in the skin.

The other data set concerns one of the first successful trials of adjuvant chemotherapy for 929 patients with colon cancer [23]. 888 patients remain after removing missing values. There are two events in this data set. In a first experiment (CD), the event is death while in a second experiment (CR) the event is recurrence. This data set contains 10 variables which are as follow: treatment, sex, age, obstruction of colon by tumor, perforation of colon, adherence to nearby organs, number of lymph nodes with detectable cancer, differentiation of tumor, extent of local spread and time from surgery to registration.

V. Simulation Method

In simulated experiments of this study, continuous features were generated from a normal distribution with zero mean and unit variance. The correlations between the first ten features are zero except for the first and second variable, the third and fourth, the fifth and sixth, and the seventh and eighth, having correlation coefficients 0.7, 0.3, -0.7 and -0.3, respectively. The correlations between the second ten features, the third ten features up to end are similar to the first ten features. Similar methods of data set generation has been previously applied in the literature [18]. To generate weight vector of features, *w*, half of weights are set to zero and the rest are simulated from a normal distribution with zero mean and unit variance. There are some previous studies which have used similar methods of data set generation [6, 24, 25]. The event (failure) time follows the exponential distribution with parameter equal to $w^T x$, where *x* is the feature vector. So the survival time is associated to half of features through the prognostic index, $w^T x$. The censoring time also follows an exponential distribution with parameter equal to $cw^T x$ where the coefficient c is used to control the censoring percentage in the training and test sets. Similar methods of data set generation has been previously applied in the literature [6, 26].

We were interested to evaluate the effect of censoring percentage, number of model features and the sample size on the model performance. In the first setting, to evaluate the effect of censoring percentage, we generated datasets with different censoring rates: $0.1, 0.2, \dots, 0.9$. For each censoring percentage, we generated 50 datasets with 20 continuous features. These data sets included 200 training and 1000 test observations [18].

A clinical data set often includes both categorical and continuous features. So, to investigate the impact of categorical features on model performance, in the second setting, we generated data sets similar to previous setting except that 16 features were generated from a Bernoulli distribution with different nonzero means and 4 features were generated from a normal distribution with zero mean and unit variance.

To evaluate effectiveness of number of features, in the third setting, we generated data sets with different number of features: $10, 20, \dots, 120$. For each given number of features, 50

1. Data are available at
https://vincentarelbundock.github.io/Rdatasets/datasets.html

data sets with censoring rate equal to 0.5 including 200 training and 1000 test observations were generated.

In the fourth setting, we generated data sets with different training sample sizes: 50, 100, 200, 350, 500, 750, 1000 and 1500. The testing sample size was set equal to 4 times the training sample size. In this setting, 50 data sets with 20 continuous features and censoring rate equal to 0.5 were generated for each given sample size.

VI. Results

Three real data sets were used for evaluating performance of SVR models. Each experiment was repeated 100 times with random partitioning of training and testing such that in each experiment 2/3 of the data set was used for training set and the rest was used for test. In all experiments, real and artificial data sets, the training set was used for learning the models and tuning the parameters. Models performance was evaluated based on the test data.

All SVR models were implemented in Matlab using the Mosek optimization toolbox for Matlab and Yalmip toolbox. Also we used ‘R’, Version 3.1.2 for implementing Cox model and calculating some performance measures.

TABLE I presents the censoring percentage, number of features and total sample size for five experiments with real data sets. For each experiment, performance measures of Cox and SVR models are displayed in TABLE II.

Statistically significant differences between SSVR and other models are indicated based on the Wilcoxon rank sum test. In experiments PT and PD, SVCR significantly outperformed Cox. These experiments had the highest censoring percentage and number of features among the five real experiments. In the HA data set, censoring times for all censored observations were similar and were equal to the follow-up period and we were not able to compute MRL for this data set. In the rest of the experiments, SSVR-MRL performed slightly better than other models but these differences were not significant. Real data sets did not indicate significant differences between SSVR and SSVR2 or SSVRP. In some experiments, performance of SSVR model was significantly better than L1-SSVR.

Figures indicate performance measures of Cox and SVR models using artificial data sets. In these figures, reported measures are median performance of 50 simulated experiments.

Fig. 1 shows performance measures of Cox and SSVR models for data sets with different censoring percentages. The left plots are related to data sets with only continuous features and the right plots concern the data sets which also have categorical features. All plots show that Cox outperforms SSVR for lower censoring percentages and when censoring percentage is high, SSVR outperforms Cox. Performance of SSVR and SSVR-MRL models are compared in fig. 2. This figure indicates that SSVR-MRL slightly outperforms SSVR for almost different censoring percentages but this difference is very small. In this figure similar to Fig.1, the results for two data sets, the data sets containing categorical features and data sets with only continuous features are similar except that plots for data sets with only continuous features exhibit smoother curves. Performance measures of two models, SSVR and SSVR2, for data sets with different censoring percentages are displayed in Fig. 3. All plots show SSVR outperforms SSVR2 for all censoring percentages.

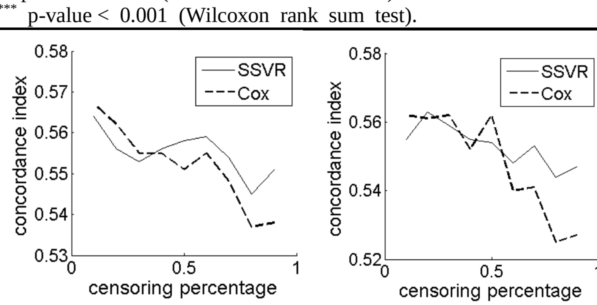
TABLE I. Some Characteristics of Real Data Sets

Data sets	Sample size	Number of features	Censoring percentage
HA	197	7	86.3
PD	276	17	59.78
PT	276	17	93.48
CD	888	10	51.58
CR	888	10	49.78

TABLE II. Comparison of Different Survival Models on Six Real Experiments. Median and Median Absolute Deviation of 100 Random Splits into Train-Test Sets are Given. Statistical Significant Differences Between Model SSVR and the Other Models are Indicated Based on the Wilcoxon Rank Sum Test

Data sets	method	c-index	logrank test ststistic	Hazard ratio
HA	Cox	0.62 ± 0.05	1.24 ± 1.11	1.27 ± 0.17 **
	SSVR	**0.62 ± 0.05**	**1.15 ± 1.04**	**1.51 ± 0.30**
	SSVRP	0.61 ± 0.05	1.21 ± 1.07	1.46 ± 0.24
	L1-SSVR	0.61 ± 0.05	0.96 ± 0.80	1.46 ± 0.24
	SSVR2	0.60 ± 0.05*	1.08 ± 0.92	1.39 ± 0.23
PD	Cox	0.82 ± 0.02 ***	23.08 ± 5.22 **	2.66 ± 0.30 ***
	SSVR	**0.84 ± 0.01**	**26.25 ± 5.11**	**3.10 ± 0.56**
	SSVR-MRL	0.84 ± 0.01	26.12 ± 5.78	3.13 ± 0.53
	SSVRP	0.84 ± 0.01	26.12 ± 4.22	3.10 ± 0.55
	L1-SSVR	0.82± 0.02 **	25.40 ± 5.87	2.95 ± 0.51 *
	SSVR2	0.83 ± 0.01	27.37 ± 5.67	3.07 ± 0.55
PT	Cox	0.70 ± 0.05 **	2.13 ± 1.50 **	1.41 ± 0.24 ***
	SSVR	**0.74 ± 0.06**	**3.18 ± 2.24**	**2.11 ± 0.49**
	SSVR-MRL	0.76 ± 0.06	3.91 ± 2.40	2.12 ± 0.49
	SSVRP	0.75 ± 0.06	3.38 ± 2.07	2.17 ± 0.53
	L1-SSVR	0.69 ± 0.06 ***	1.85 ± 1.65**	1.95 ± 0.51
	SSVR2	0.74 ± 0.06	3.14 ± 1.92	2.14 ± 0.48
CD	Cox	0.64 ± 0.01	20.81 ± 5.50	1.56 ± 0.06
	SSVR	**0.64 ± 0.01**	**21.59 ± 5.53**	**1.49 ± 0.07**
	SSVR-MRL	0.66 ± 0.01	22.63 ± 5.51	1.50 ± 0.09
	SSVRP	0.64 ± 0.01	21.93 ± 5.84	1.49 ± 0.07
	L1-SSVR	0.64 ± 0.01	21.34 ± 4.97	1.45 ± 0.06 ***
	SSVR2	0.64 ± 0.01	22.17 ± 6.41	1.51 ± 0.07
CR	Cox	0.64 ± 0.01	18.87 ± 4.96	1.57 ± 0.06
	SSVR	**0.65 ± 0.01**	**19.71 ± 3.63**	**1.47 ± 0.08**
	SSVR-MRL	0.65 ± 0.01	22.63 ± 5.51	1.50 ± 0.09
	SSVRP	0.65 ± 0.01	20.51 ± 4.38	1.47 ± 0.08
	L1-SSVR	0.64 ± 0.01 *	19.24 ± 5.28	1.49 ± 0.08
	SSVR2	0.65 ± 0.01	21. 42 ± 4.49	1.45 ± 0.09

* p-value < 0.05 (Wilcoxon rank sum test).
** p-value < 0.01 (Wilcoxon rank sum test).
*** p-value < 0.001 (Wilcoxon rank sum test).



(a) (d)

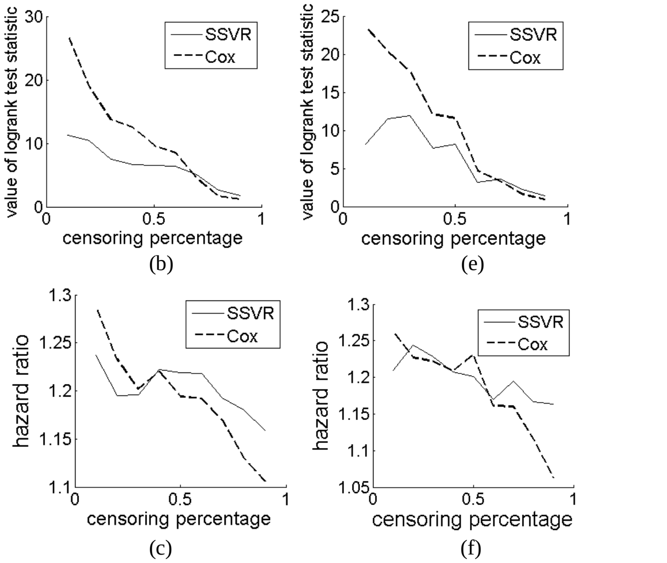


Fig. 1. (a), (b), (c): performance measures of Cox and SSVR models for artificial data sets with 20 continuous features and different censoring percentages, (d), (e), (f): performance measures of Cox and SSVR model for artificial data sets with categorical and continuous features and different censoring percentages. These measures are obtained using median measures of 50 artificial train-test sets

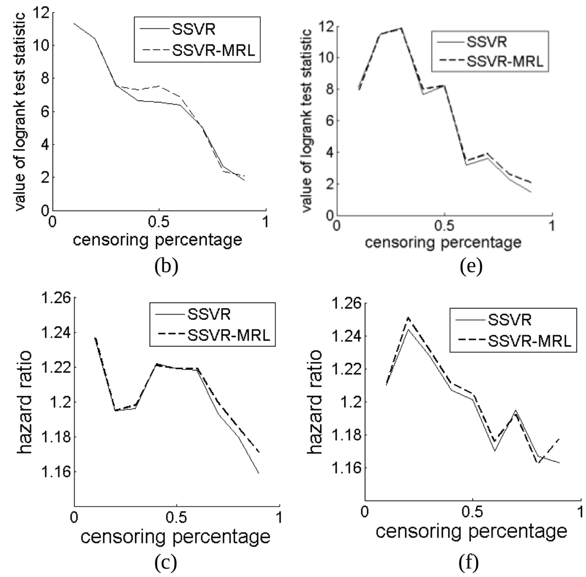
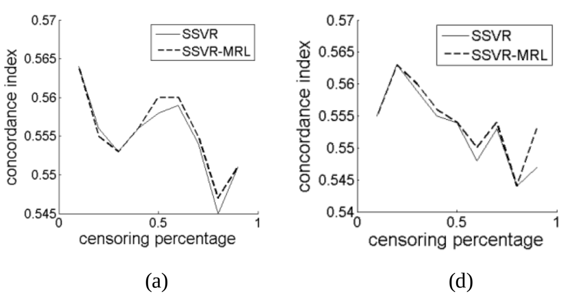


Fig. 2. (a), (b), (c): performance measures of SSVR and SSVR-MRL models for artificial data sets with 20 continuous variables and different censoring percentages, (d),(e), (f): performance measures of SSVR and SSVR-MRL models for artificial data sets with categorical and continuous features and different censoring percentages. These measures are obtained using median measures of 50 artificial train-test sets

Fig. 4 shows performance measures of three models, SSVR, SSVRP and L1-SSVR for data sets with different censoring percentages. In this figure, SSVR is compared to SSVRP and L1-SSVR. The plots indicate that performance of SSVR, SSVRP and L1-SSVR are comparable. The left plots of Fig. 5 display performance measures of SSVR and Cox for data sets with different number of features. The plots indicate that performance of two models, Cox and SSVR, decrease as number of model features increases but the amount of reduction for SSVR is lower than Cox. Therefore, for data sets with higher number of features, SSVR outperforms Cox. Performance measures of SSVR and Cox for data sets with different sample sizes are shown in right plots of fig. 5. These plots indicate that performance of both SSVR and Cox improves as training sample size increases. Also two plots in this figure indicate that for lower training sample size, performance of SVR is a little better than Cox. When training sample size slightly increases, Cox outperforms SVR and for large training sample size, two models perform similarly.



VII. Discussion

The results of current study indicated that performance measures of SSVR and Cox decreased as censoring percentage increased, but the amount of reduction for SSVR was lower than Cox. For data sets with a high censoring percentage, SVR models outperformed the traditional Cox model.

Shivaswamy et al. [7] also evaluated the effect of censoring rate on performance of SVR model. They did not use simulated data and changed survival times in some real data sets to obtain data sets with different censoring percentages. They did not use Cox model and compared SVR with a survival model based on Gaussian process. They similar to current study found that performance of two mentioned models decreased as censoring rate increased and the amount of reduction for SVR is lower than the Gaussian process model.

Van Belle et al. [17, 18] compared performance of some survival models on six clinical data sets and three high dimensional data sets. They compared performance of some survival models with the SVCR2 model (the model with both regression and ranking constraints) and found that the differences of performance measures between SVCR2 and Cox were not significant.

In our study, SVCR model was compared with other survival models and the findings based on two real data sets indicated that SVCR significantly outperformed Cox model.

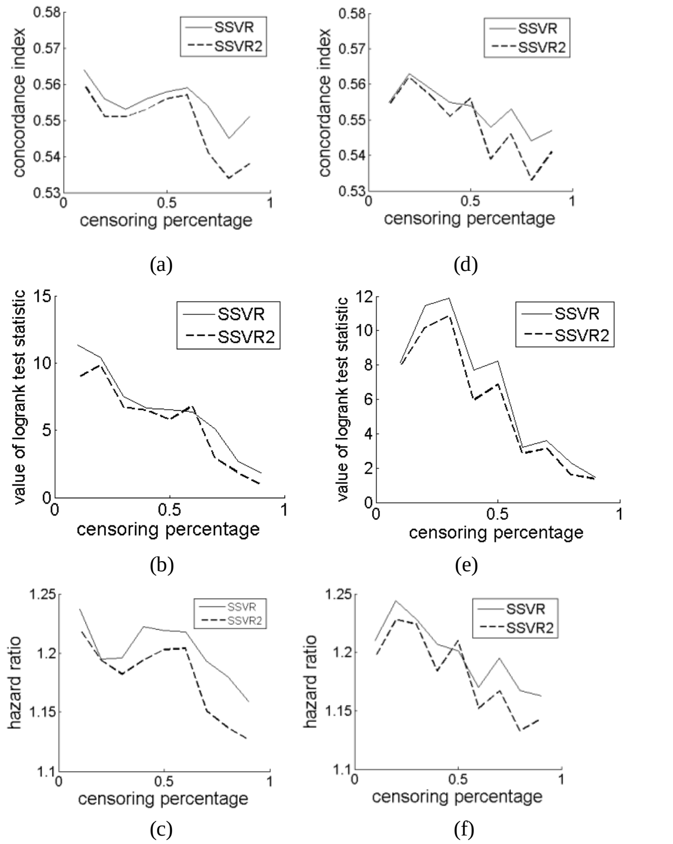


Fig. 3. figures (a), (b), (c): performance measures of SSVR and SSVR2 models for artificial data sets with 20 continuous variables and different censoring percentages, (d), (e), (f): performance measures of SSVR and SSVR2 models for artificial data sets with categorical and continuous features and different censoring percentages

Van Belle et al. [18] using clinical data sets found that differences between SVCR2 and SVCR were not significant. This result is Similar to our results for real data sets. They also yielded that for some high dimensional data sets that SVCR significantly outperformed SVCR2. Our simulated data sets also showed that SVCR slightly outperformed SVCR2. SSVR is a simpler model with one parameter while SSVR2 has two parameters and requires much time for tuning the parameters of model. Therefore, SSVR has better performance and less time complexity than SSVR2.

Some studies used a two-sided loss function for uncensored observations and a one-sided one for censored observations [6, 7, 17, 18]. In current study a tow-sided loss function was used for all observations. The results indicated that this loss function improves model performance slightly but the amount of improvement is not significant. Khan et al. [16] also applied a two-sided loss function for censored observations but their method is different from used method in this study. They entered some parameters in model to consider a two-sided loss functions for all observations and different losses for errors of underestimation and overestimation. The results of their study using five real clinical data sets indicated that SVR outperformed Cox. In contrast to current study, their model contains many parameters and requires much time for tuning the parameters of model.

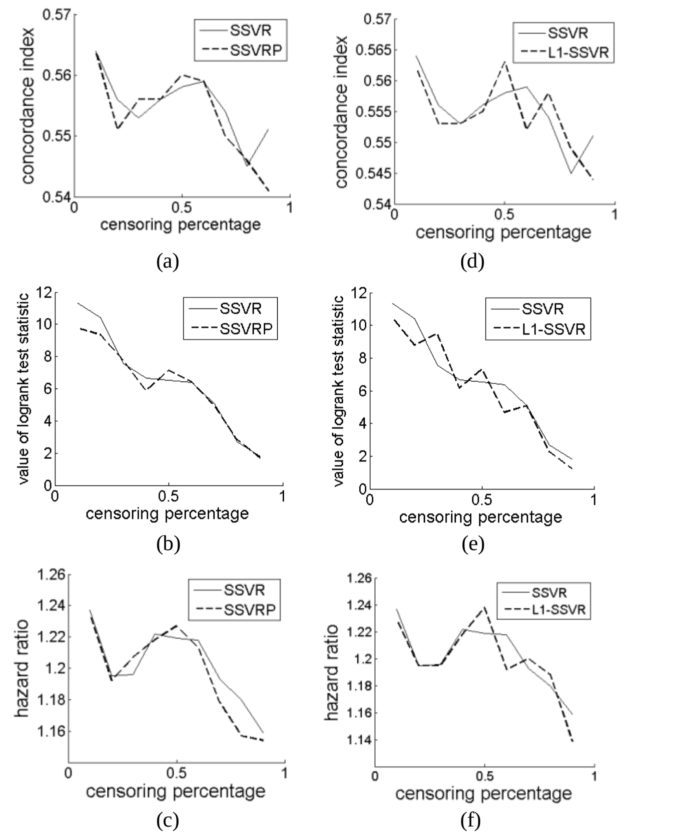


Fig. 4. (a), (b), (c): performance measures of SSVR and SSVRP models for artificial data sets with 20 continuous variables and censoring percentage equal to 0.5, (d), (e), (f): performance measures of SSVR and L1-SSVR2 models for artificial data sets with categorical and continuous features and censoring percentage equal to 50

Current study indicated that when the number of features was large, SVR outperformed Cox and when number of model features compared with the sample size was large enough, Cox was not able to be trained. Due and Dua [20], also using a breast cancer data set, yielded that feature selection improved performance of Cox and SVR and the amount of improvement for Cox was more than SVR. They reported that SVR outperformed Cox on the initial data set. After using feature selection, fewer features were included in the model and performances of Cox and SVR was similar. Some studies also reported good performance of SVR in dealing with high-dimensional data [7, 17].

There are limited papers which used artificial survival data sets for training survival SVR models. Shiao and Cherkassky[26] proposed two SVM methods to apply in survival analysis. The authors evaluated their methods using real data sets and artificial data sets. In contrast to current study, they used SVM models for classification of survival data. Van Belle et al. [6, 18] used limited artificial data sets for evaluating the performance of a SVR model with only ranking constraints. Liu et al. [25] also used limited artificial data sets to evaluate a novel survival L1-SVR method for large scale data sets. Goldberg and Kosorok [27] proposed a novel SVR method for censored data and used a simulation study for evaluating their method. The proposed survival SVR model in their study is completely different from methods studied in current paper and other studies in the literature. Apart from this study, to the best of our knowledge, there is no previous survival study which uses simulated data sets for comparing performance of Cox and SVR.

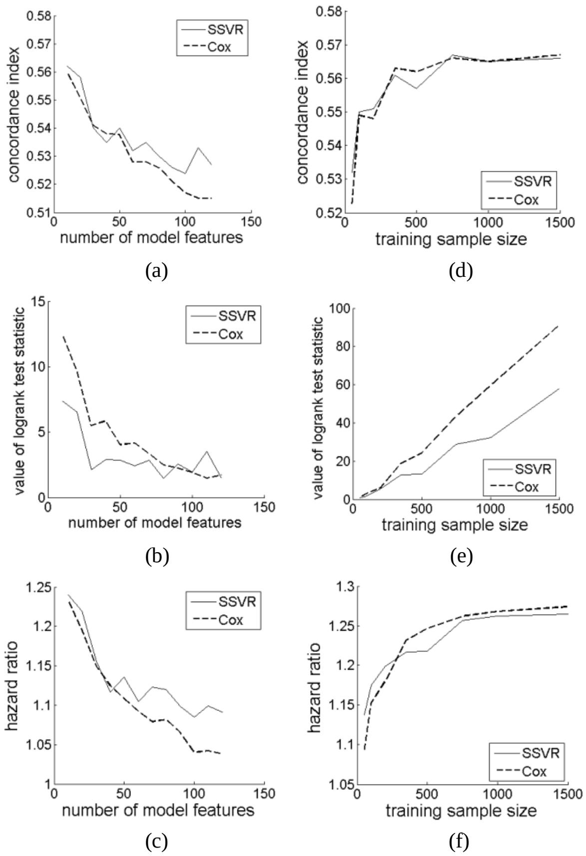


Fig. 5. (a), (b), (c): performance measures of SSVR and Cox models for artificial data sets with different number of model features, (d),(e) and (f): performance measures of SSVR and Cox models for artificial data sets with different training sample size. Censoring percentage of datasets are equal to 50

L1-SSVR and SSVRP (model with positivity constraints) are employed for feature selection. This study indicated that there were not significant differences between performances of SSVR and SSVRP. However for some real data sets it was found that SSVR significantly outperformed L1-SSVR. Cox model is a semiparametric model that needs to check the proportional hazard assumption. This model is only able to expose linear effects of features on hazard while some features may have a non-linear effect. For using of SVR models one does not have to check such assumptions. Also, the findings showed that for data with high censoring percentage or many features, SVR models have desirable performance. Due to good performance of SVR models for survival analysis, It is suggested that in future studies, these models are extended to other survival subjects such as competitive risks and analysis of recurrent events data.

VIII. Conclusion

The results of current study for two real data sets showed that if the censoring percentage of the clinical data sets is high and the model includes many features, SVR significantly outperforms traditional Cox model. Experiments with the artificial data sets in current study indicated that when censoring percentage of a clinical data set is high, SVR outperforms Cox. If the censoring percentage is low, Cox has a better performance. However, SVR has the advantage of not requiring the proportional hazard assumption. Also, when the data set includes many features, SVR outperforms Cox. In addition, if the training set size is large enough, two models perform similarly.

The use of a two-sided loss function using MRL did not improved performance of SVR model. Real data sets did not indicate significant differences between SSVR (model with only regression constraint) and SSVR2 (model with regression and ranking constraints). However, SSVR had a better performance compared to SSVR2 using simulated data sets. For two real data sets, performance of L1-SSVR significantly was worse than the SSVR model.

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References

[1] J.P. Klein and M.L. Moeschberger, Survival Analysis: Techniques for Censored and Truncated data. 2003: Springer Science & Business Media.

[2] J. Faradmal, A. Kazemnejad, R. Khodabakhshi, M.-R. Gohari, and E. Hajizadeh, Comparison of three adjuvant chemotherapy regimes using an extended log-logistic model in women with operable breast cancer. Asian Pac J Cancer Prev, 2010. 11(2): pp. 353-8.

[3] J. Faradmal, A. Talebi, A. Rezaianzadeh and H. Mahjub, Survival analysis of breast cancer patients using cox and frailty models. Journal of research in health sciences, 2012. 12(2): pp. 127-130.

[4] J. Faradmal, A.R. Soltanian, G. Roshanaei, R. Khodabakhshi, and A. Kasaeian, Comparison of the performance of log-logistic regression and artificial neural networks for predicting breast cancer relapse. Asian Pacific journal of cancer prevention: APJCP, 2014. 15(14): pp. 5883-5888.

A. Giordano, M. Giuliano, M. De Laurentiis, A. Eleuteri, F. Iorio, et al., Artificial neural network analysis of circulating tumor cells in metastatic breast cancer patients. Breast cancer research and treatment, 2011. 129(2): pp. 451-458.

[5] V. Van Belle, K. Pelckmans, J.A. Suykens and S.V. Huffel, Learning transformation models for ranking and survival analysis. The Journal of Machine Learning Research, 2011. 12: pp. 819-862.

[6] P.K. Shivaswamy, W. Chu and M. Jansche. A support vector approach to censored targets. in Data Mining, 2007. ICDM 2007. Seventh IEEE International Conference on. 2007. IEEE.

[7] B.E. Boser, I.M. Guyon and V.N. Vapnik. A training algorithm for optimal margin classifiers. in Proceedings of the fifth annual workshop on Computational learning theory. 1992. ACM.

[8] A.J. Smola and B. Schölkopf, A tutorial on support vector regression. Statistics and computing, 2004. 14(3): pp. 199-222.

[9] J. Che, J. Wang and G. Wang, An adaptive fuzzy combination model based on self-organizing map and support vector regression for electric load forecasting. Energy, 2012. 37(1): pp. 657-664.

[10] Kazem, E. Sharifi, F.K. Hussain, M. Saberi, and O.K. Hussain, Support vector regression with chaos-based firefly algorithm for stock market price forecasting. Applied Soft Computing, 2013. 13(2): pp. 947-958.

[11] J.G. Silva Fonseca, T. Oozeki, T. Takashima, G. Koshimizu, Y. Uchida, et al., Use of support vector regression and numerically predicted cloudiness to forecast power output of a photovoltaic power plant in

Kitakyushu, Japan. Progress in photovoltaics: Research and applications, 2012. 20(7): pp. 874-882.

[12] J. Wang, L. Li, D. Niu and Z. Tan, An annual load forecasting model based on support vector regression with differential evolution algorithm. Applied Energy, 2012. 94: pp. 65-70.

[13] H. Yijun, Y. Shu, H. Minghuang, Y. Xiaowei, Q. Fang, et al., Application of support vector machine to predict 5-year survival status of patients with Nasopharyngeal Carcinoma after treatment. The Chinese-German Journal of Clinical Oncology, 2006. 5(1): pp. 8-12.

[14] Z. Ding. The application of support vector machine in survival analysis. in Artificial Intelligence, Management Science and Electronic Commerce (AIMSEC), 2011 2nd International Conference on. 2011. IEEE.

[15] F.M. Khan and V.B. Zubek. Support vector regression for censored data (SVRc): a novel tool for survival analysis. in Data Mining, 2008. ICDM'08. Eighth IEEE International Conference on. 2008. IEEE.

[16] V. Van Belle, K. Pelckmans, S. Van Huffel and J.A. Suykens, Improved performance on high-dimensional survival data by application of Survival-SVM. Bioinformatics, 2011. 27(1): pp. 87-94.

[17] V. Van Belle, K. Pelckmans, S. Van Huffel and J.A. Suykens, Support vector methods for survival analysis: a comparison between ranking and regression approaches. Artificial Intelligence in Medicine, 2011. 53(2): pp. 107-118.

[18] V. Van Belle, K. Pelckmans, J.A. Suykens and S. Van Huffel, Additive survival least-squares support vector machines. Statistics in Medicine, 2010. 29(2): pp. 296-308.

[19] Du and S. Dua, Cancer prognosis using support vector regression in imaging modality. World journal of clinical oncology, 2011. 2(1): pp. 44.

[20] V. Van Belle, K. Pelckmans, J.A. Suykens and S. Van Huffel. On the use of a clinical kernel in survival analysis. in ESANN. 2010.

[21] T.M. Therneau and P.M. Grambsch, Modeling survival data: extending the Cox model. 2000: Springer Science & Business Media.

[22] C.G. Moertel, T.R. Fleming, J.S. Macdonald, D.G. Haller, J.A. Laurie, et al., Levamisole and fluorouracil for adjuvant therapy of resected colon carcinoma. New England Journal of Medicine, 1990. 322(6): pp. 352-358.

[23] H.-T. Shiao and V. Cherkassky. SVM-based approaches for predictive modeling of survival data. in The 2013 International Conference on Data Mining. 2013.

[24] Z. Liu, D. Chen, G. Tian, M.-L. Tang, M. Tan, et al., Efficient support vector machine method for survival prediction with SEER data, in Advances in Computational BiologySpringer. 2010. pp. 11-18.

[25] H.-T. Shiao and V. Cherkassky. SVM-based approaches for predictive modeling of survival data. in Proceedings of the International Conference on Data Mining (DMIN). 2013. The Steering Committee of The World Congress in Computer Science, Computer Engineering and Applied Computing (WorldComp).

[26] Y. Goldberg and M.R. Kosorok, Support vector regression for right censored data. arXiv preprint arXiv:1202.5130, 2012.

Data Security Using Cryptography and Steganography Techniques

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***Abstract*—Although cryptography and steganography could be used to provide data security, each of them has a problem. Cryptography problem is that, the cipher text looks meaningless, so the attacker will interrupt the transmission or make more careful checks on the data from the sender to the receiver. Steganography problem is that once the presence of hidden information is revealed or even suspected, the message is become known. According to the work in this paper, a merged technique for data security has been proposed using Cryptography and Steganography techniques to improve the security of the information. Firstly, the Advanced Encryption Standard (AES) algorithm has been modified and used to encrypt the secret message. Secondly, the encrypted message has been hidden using method in [1]. Therefore, two levels of security have been provided using the proposed hybrid technique. In addition, the proposed technique provides high embedding capacity and high quality stego images.**

Keywords—Image Steganography; Pixel Value Difference (PVD); Encryption; Decryption; Advance encryption standard (AES)

I. INTRODUCTION

Information transmission through internet may include sensitive personal data which may be intercepted. Also, there are many applications on the internet and many web sites require the users to fill forms that include sensitive personal information such as telephone numbers, addresses, and credit card information. So, the users may need private and secure communications for many reasons such as protect their confidential information from hackers during it passed over an open channel, so the confidentiality and data integrity are required to protect against unauthorized access and use. Cryptography and steganography are the common methods to secure communications [2].

Cryptography is the science of using mathematics to encrypt and decrypt data to keep messages secured by transforming intelligible data form (plaintext) into unintelligible form (ciphertext). The term cryptography has come from the Greek word “kryptós” standing for “hidden” and “gràphin” standing for “writing”. Thus, the proper meaning of cryptography is “hidden writing” [3, 4]. Any cryptosystem consists of plaintext, encryption algorithm, decryption algorithm, Cipher text, and Key. Plaintext is message or data which are in their normal, readable (not encrypted) form. Encryption is the process of converting plaintext to cipher text by using key. Cipher text results from encryption by applying the encryption key on the plaintext. Decryption is the process of retrieving the plaintext back from the cipher text. The Key is used info to control the cryptosystem (cipher system), and it is known by the sender and receiver only [3, 5]. While cryptography is very powerful for securing data; the cryptanalysts could success to break the ciphers by analyzing the contents of cipher text to get back the plaintext [3].

Cryptographic systems are generally classified into three independent dimensions [3]:

A. Type of Operation on Plaintext

There are two types of operations that are occurred on plaintext to transform plaintext to cipher text. According to the first operation, each element in plaintext (i.e., bit, letter, group of bits or letters) is substituted for one another in the ciphertext. In this type of operation, a one-to-one mapping between the elements such as Caesar cipher [5]. The principle of the second type of operation is that each character in plaintext is transposed with one another based on a mapping dictated by the key. In this type, the plaintext characters stay the same but they are just moved into different positions such as Rail Fence cipher. Most systems, referred to as product systems, involve multiple stages of substitutions and transpositions.

B. The Number of Used Keys

If the sender and the receiver use one key to encrypt and decrypt the plaintext, the system is referred to as symmetric, single key, secret key or conventional encryption. Symmetric encryption is fairly straightforward and very fast. If the sender and receiver use different keys, public key and private key, to encrypt and decrypt the plaintext respectively, the system is referred to as asymmetric, two – key, or public key encryption.

C. The Way in which The Plain Text is processed

Block cipher operates on fixed-length groups of bits, called blocks, and produces an output block for each input block. A stream cipher operates on each plaintext element continuously, and produces one element at a time, as it goes along.

On the other hand, Steganography is considered the art and science of hiding information in other information. The word Steganography is derived from the Greek words “steganos” meaning “impenetrable” and, “grafia” meaning “writing” defining it as “impenetrable writing” [4, 6]. There are two common techniques for image embedding in steganography; spatial domain and transform domain.

According to spatial domain embedding, the messages are embedded directly into the Least Significant Bits (LSBs). The least significant bits (LSB) insertion method is considered the most common and simplest Steganography method. According to transform domain embedding, the messages are embedded by modifying frequency coefficients of the cover image such as the Fourier transform, discrete cosine transform, or the wavelet transform [7].

Image steganography system is comprised two algorithms, one for embedding and one for extraction. The embedding process hides a secret message within a cover media (cover image), and the result of embedding process is stego image. The main issue is that the secret message will not be unnoticed if a third party tries to intercept the cover media (cover image). The extraction process is simply because it is the inverse of the embedding process, where the secret message is revealed at the end [8].

To evaluate the quality of image, stego image and cover image are compared. This requires a measure of stego-image quality, commonly used measures are Mean Square Error (MSE), and Peak Signal-to-Noise Ratio (PSNR). Mean Square Error (MSE) is used to quantify the difference between the initial (cover) and the distorted or noisy (Stego) image [8, 9].

$$\mathrm{MSE} = \frac{1}{\mathrm{MN}} \sum_{x=1}^{M} \sum_{y=1}^{N} (S_{x\,y} - C_{x\,y}) \;\ldots\ldots\ldots\ldots\; (1)$$

Where X and Y are the image coordinates, M and N are the number of rows and columns in the input images, respectively. Sxy is the generated stego-image and Cxy is the cover image [7].

Peak Signal-to-Noise Ratio (PSNR) is used to measure image distortion due to embedding and it is measured in decibels (dB) [9, 10].

PSNR=10 log 10 (C2max /MSE) …..…………… (2)

Where, Cmax holds the maximum value in the image that is 255 and MSE is the mean square error which is determined by equation (1).

The steganography approaches can be divided into three types [11]:

1) Pure Steganography; it is a technique simply uses the steganography approach only without combining other methods. It is working on hiding information within cover carrier.

2) Secret Key Steganography; it uses the combination of the secret key cryptography technique and the steganography approach. The idea of this type is to encrypt the secret message by secret key technique and then hide the encrypted data within cover carrier.

3) Public Key Steganography; it is the combination of the public key cryptography approach and the steganography approach. The idea of this type is to encrypt the secret data using the public key approach and then hide the encrypted data within cover carrier.

The Difference between Cryptography and Steganography [8, 11]:

- Cryptography prevents unauthorized party from discovering the content of communication but Steganography prevents discovery of the existence of communication (i.e., Cryptography makes data gibberish and known the message passing while Steganography tends to conceal presence of hidden data and unknown the message passing).
- Cryptography alters the structure of secret message while Steganography does not alter the structure of secret message.
- Cryptography is more common technology than Steganography technology.
- The most algorithms of Cryptography are well known, but the algorithms of Steganography are still being developed by certain formats.
- In Cryptography, the strong algorithm depends on the key size, the more key size; the more expensive computing power is required to decrypt ciphertext. In Steganography, once the hidden message is detected, the message is become known.
- Cryptography can provide all security objectives by implementing the public and private key(s) with hash functions or authentication codes or digital signatures. Steganography cannot provide most of security objectives (Integrity, authenticity, non-repudiation) by itself without using the cryptographic techniques. However it provides confidentiality by itself because mostly, the concerning person knows that the message is hidden in what kind of medium [12].

In this paper, the secret Key steganography approach is used to improve security by using modified AES and method in [1] which includes PVD_MPK and MSLDIP-MPK methods to encrypt and hide the message in cover image. Therefore, if an attacker doubts about the stego image and tries to detect the message from the stego image, he would still require the key to decrypt the encrypted message.

The rest of this paper is organized as follows; related work will be discussed in section 2 and the proposed method will be presented in section 3. Then experimental results of the proposed method will be given in section 4. Finally, section 5 concludes the paper and future work.

II. Related Work

There are many methods have been used to provide data security whether by using encryption, steganography or combination between them. Advance encryption standard (AES) method, it is also known as Rijndael, is a symmetric-key block cipher [12]. Unlike DES method, AES method is a non-Feistel cipher that encrypts and decrypts a data block of 128 bits. It uses 10, 12, or 14 rounds. The key size, which can be 128, 192, or 256 bits, and the number of rounds depend on the key size because it allows the secret key to be expanded to produce sub key for each round. In AES method, the input and output sequences have the same length [12, 13]. According to AES method, substitution byte, shift rows, mixing column and key adding steps are implemented in every encryption round to encrypt the message, but the Mixing Column step doesn't included in the last round. In the decryption, the four steps are implemented in the reverse way. Also, the inverse of mixing column step doesn't include in the last round of the decryption. The pseudo code of AES is as follows [13]:

1. InitialRound(State,RoundKey)
   {
   AddRoundKey (State,RoundKey);
   }
2. Rounds (State,RoundKey)
   {
   SubBytes (State);
   ShiftRows(State);
   MixColumn(State);
   AddRoundKey(State,RoundKey);
   }
3. FinalRound(State,RoundKey)
   {
   SubBytes (State) ;
   ShiftRows(State) ;
   AddRoundKey(State,RoundKey);
   }

Where SubBytes is a non-linear substitution step where each byte is replaced with another according to a lookup table after each byte is interpreted as two hexadecimal digits. ShiftRows is a transposition step where it performs a circular rotates on each row of 0, 1, 2 & 3 places for respective rows. MixColumns is a mixing operation which operates on the columns of the state. It transforms each column of the state to a new column. AddRoundKey is precedes one column at a time. AddRoundKey adds a round key word with each state column matrix using bitwise XOR operation [14]. The advantages of using AES algorithm are; it is more secure, support larger key sizes than DES, faster in both hardware and software, reasonable cost, and its main characteristics flexibility and simplicity [15].

In [16], a method has been proposed based on spatial domain instead of using LSB1 (First Least Significant Bit) of the cover image for embedding the message bits, LSB-3 (Third Least Significant Bit) has been used to hold the message bits and LSB-1, LSB-2 may also be modified. According to this method, it is found that the LSB-1 method has more PSNR (Peak Signal to Noise Ratio) values which mean that the image's quality using LSB-1 method is better than that LSB-3 method. Also, the capacity is still the same. So, the basic LSB-1 method has better results than the proposed LSB-3 method.

In [1], a steganography algorithm has been proposed by combining PVD-MPK and MSLDIP-MPK methods. The idea of this proposed algorithm is that using the digits of MPK encoding instead of bits of secret message in hidden step to increase the capacity and quality because MPK encoding represents each character by two digits instead of 8 bits. As an example, the letter “a” will be represented as 2 1, this mean that the letter "a" can be typed by pressing the key no.# (2) in the keypad only one time. Firstly, the cover image is divided into non-overlapping blocks, where each block consists of two consecutive pixels and each byte in the message is converted to Mobile Phone Keypad (MPK) format, then the difference value d_i for each block of two consecutive pixels P_i , P_{i+1} is calculated . If the difference value is larger than 19, this means that the two pixels are located in high level (edge area) and MSLDIP-MPK method is used to hid data to increase capacity. Therefore, each last digit in two pixel of block is replaced by the digit value of the secret message. On the contrary, if the difference value is smaller than 19, this means that the two pixels are located in low level (smooth area) and PVD_MPK method is used to hide data to increase image quality. Then, find the optimum range R_i for the difference d_i where $R_i \in [l_i , u_i]$, and l_i and u_i are the lower and upper bound of each range of the range table and $l_i \leq d_i \leq u_i$ because this method uses the ranges (0-4), (5-9), (10-14), (15-19), (20-24), (25-29) etc. to calculate the new difference and make it nearly as possible to the original difference. The new difference is calculated by equation (3):

$$d_i` = l_i + b/2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where d_i` is the new difference, l_i is the lower bound of the range, and b is the digit that needs to be hidden. Replace the old difference with the new difference by using Equation (4):

$$(p`_i, p`_{i+1}) = \begin{cases} \left(p_i + \left\lceil \frac{m}{2} \right\rceil, p_{i+1} - \left\lfloor \frac{m}{2} \right\rfloor\right), \\ \text{if } p_i \geq p_{i+1} \text{ and } d'_i > d_i; \\ \left(p_i - \left\lfloor \frac{m}{2} \right\rfloor, p_{i+1} + \left\lceil \frac{m}{2} \right\rceil\right), \\ \text{if } p_i < p_{i+1} \text{ and } d'_i > d_i; \\ \left(p_i - \left\lceil \frac{m}{2} \right\rceil, p_{i+1} + \left\lfloor \frac{m}{2} \right\rfloor\right), \\ \text{if } p_i \geq p_{i+1} \text{ and } d'_i \leq d_i; \\ \left(p_i + \left\lceil \frac{m}{2} \right\rceil, p_{i+1} - \left\lfloor \frac{m}{2} \right\rfloor\right), \\ \text{if } p_i < p_{i+1} \text{ and } d'_i \leq d_i. \end{cases} \quad \ldots.. (4)$$

This equation adjusts the value of p_i and p_{i+1} to modify the difference. Where, m is the difference between the original and the new differences (i.e., m= $|d_i - d_i`|$), $p_i$ and $p_{i+1}$ are the first and second pixel in a block before embedding, and $p_i$` and p_{i+1}` are the first and second pixel in a block after embedding . Then, Compute the remainder value by:

$$\text{Rem} = b \bmod 2 \ldots\ldots\ldots\ldots. \quad (5)$$

If Rem equal 1, make p_i odd, else make p_i even. The experimental results showed that the PSNR and Maximum Hidden Capacity (MHC) of this technique are high comparing to the existed techniques.

In [17], a proposed technique has been introduced. The results of the proposed technique prove that it is more secure than other techniques against statistical attacks which are commonly used in steganalysis. This is because it ranked images in a user's library based on their suitability as cover objects for some data. The process is repeated for each image in a user’s image library. Each bit of the encrypted data is compared to the least significant bit of the pixel bytes in an image. The comparisons are made starting from the first byte until the last byte in the image that permits all data to be hidden in that image. By matching data to an image, there is less chance of an attacker being able to use steganalysis to recover the data. The image is then given a rank based on the percentage of least significant bits that match the encrypted data bits. Before hiding the data in an image, the data is first encrypted using the RSA public key algorithm, and then the encrypted data is hidden by using LSB.

In [18], a new method has been proposed for hiding any encrypted secret message inside a cover file. To embed a secret message file in the cover file, they have used two distinct methods; (1) they encrypt the secret message file using simple bit shifting and XOR operation in the secret message file. (2) The encrypted secret message is embedded in the cover file in alternate byte instead of changing the LSB of the cover file bytes. They change LSB and LSB+3 bits of the cover file bytes. Their method could be most appropriate for hiding any file in any standard or nonstandard cover file such as word, excel, .ppt, .exe, image, audio, video files. Also, this method may be used for sending some secret key to someone over mail as the intruder may not be able to unhide and decrypt the secret message.

III. The Proposed Method

The main objective of the proposed method is to introduce more secure communication by merging cryptography and steganography techniques to make it more difficult for a steganalyst to retrieve the plaintext of a secret message from a stego-object. The proposed method is divided into two parts. In the first part, the AES algorithm will be modified to be suitable for steganography method and it is called AES_MPK algorithm. In the second part, the AES_MPK algorithm will be merged with steganography algorithm to hide the encrypted data in image where a message being sent is concealed [1]. Therefore, two levels of security have been applied.

A. The Modified AES (AES_MPK) Algorithm

According to the modified AES_MPK algorithm, four types of transformations are used likes AES; substitution (SubBytes), permutation (ShiftRows), MixColumns, and key-adding, to provide security [13]. Because of the AES is based on the Rijndael cipher, it performs four types of transformation based on the operations in finite field GF (2^8). Several operations are defined at byte level, and used with bytes representing as elements in the finite field or Galois field GF (2^8). Then, it represents the input and the output in form of hexadecimal digits (i.e. two hexadecimal digits for each byte) [13]. Therefore, AES algorithm is modified to make the input and the output in the form of MPK digits because the PVD_MPK and MSLDIP-MPK methods use the MPK digits for hiding the data. This modified AES algorithm called AES_MPK algorithm.

The basic idea of AES_MPK algorithm is to convert each block (i.e. 16 byte) of data to MPK digits (i.e. two digits for each byte). Then each block is divided into two states; the first state represents the first digits of 16 byte and second state represents the second digits of 16 byte. Two states are filtered by replacing each digit 8 or 9 with 7 to make state suitable for operations of GF (2^3) that are applied at each stage of encryption but save them in their location in each state. Finally, apply operations of GF (2^3) in MPK digits in the four types of transformation expect 8 and 9 digits which will be replaced with 7 and keep in their location. This is because the elements of GF (2^3) are 0, 1, 2, 3, 4, 5, 6, and 7.The four types of transformation are:

1) Substitution: The first transformation is SubBytes. To substitute a byte, this requires two steps; first apply multiplicative inverse in GF (2^3) on each element in two states. Second, apply an affine transformation over GF (2^3) on each element in the two states by representing each element as 3 bits (b_0, b_1, b_2). AES_MPK depicts this transformation in matrix form as follows:

$$\begin{bmatrix} c0 \\ c1 \\ c2 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1 \\ 1 & 1 & 0 \\ 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} b0 \\ b1 \\ b2 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}$$

Where (b0, b1, b2) are bits of element before affine transformation and (c0, c1, c2) are bits of element after affine transformation.

The SubBytes stage provides confusion (i.e., it obscures the relationship between the plaintext and the ciphertext) [5]. In decryption, InvSubBytes is performed by applying affine transformation first, and then multiplicative inverse in GF (2^3) is applied. The affine transformation in decryption will be as follows:

$$\begin{bmatrix} b0 \\ b1 \\ b2 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \end{bmatrix} \begin{bmatrix} c0 \\ c1 \\ c2 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}$$

2) Permutation: Another transformation found in a round is called ShiftRows, which permutes the bytes. It performs a circular rotate on each row of 0, 1, 2 & 3 places for respective rows. This shift moves an individual byte from one column to another, and ensures that the 4 bytes of one column are spread out to four different columns. The ShiftRows stage provides diffusion of column values between columns. The rows shift to left as follows:

- Row0: No shift
- Row1: 1-byte shift
- Row2: 2-byte shift
- Row3: 3-byte shift

In decryption, InvShiftRows is performed where the circular will be shifted in the opposite direction for each row.

3) MixColumns: This stage is used to mix bytes by using matrix multiplication. It operates at the column level where each column of the state is transformed to a new column by multiplying it in constant matrix. This stage changes the bits inside a byte, based on the bits inside the neighboring bytes. We need to mix bytes to provide diffusion at the bit level.

In decryption, InvMixColumns is performed by the inverse of constant matrix in multiplication.

$$C=\begin{matrix}2&3&1&1\\1&2&3&1\\1&1&2&3\\3&1&1&2\end{matrix}\quad\xleftrightarrow{\text{Inverse}}\quad C^{-1}=\begin{matrix}5&0&6&2\\2&5&0&6\\6&2&5&0\\0&6&2&5\end{matrix}$$

Where C is constant matrix and C^{-1} is inverse constant matrix in GF (2^3)

4) AddRoundKey: the AddRoundKey stage is a simple bitwise XOR of the current block (two states) with two portions of the expanded key. Note; this is the only step which makes use of the key. This step makes the cipher as a series of XOR with expanded keys then scramble/permute block repeated. This provides efficient and highly secure.

Note that: AES has defined three versions, with 10, 12, and 14 rounds. Each version uses a different cipher key size. We work in version with 10 rounds and key size is 16 byte.

The pseudo code of the modified AES_MPK algorithm is as follows:

AES_MPK Algorithm

Input: Secret Message SM, Cipher Key K.
Output: Cipher Message CM.
Steps:
1. Make key expansion of K that produces two lists of all sub keys.
2. Partition SM to blocks (B_1, B_2, B_3 …. B_n) each block consists of 16 byte.
3. **for** each B_i block **do**
4. Convert each byte to MPK digits (two digits for each byte).
5. Divide B_i to two state arrays (4*4).
6. Filter two states.
7. Make pre round AddRoundKey which is a simple bitwise XOR of the current two states with two sub keys
8. **repeat**
9. Apply the four transformations (SubBytes, ShiftRows, MixColumns, and AddRoundKey) in two states.
10. **until** nine round.
11. At final round implements SubBytes, ShiftRows, and AddRoundKey but MixColumns is deleted.
12. Return the digits 9 and 8 in their place in each state.
13. Mix two states to be one block.
14. Convert block to characters by using MPK decoding (i.e. two digits represent character). The result represents cipher block
15. **end**
16. Concatenate the currently cipher block with the previous cipher blocks to collect CM.

The designed ciphers and inverse ciphers of ASE_MPK algorithm are as follows:

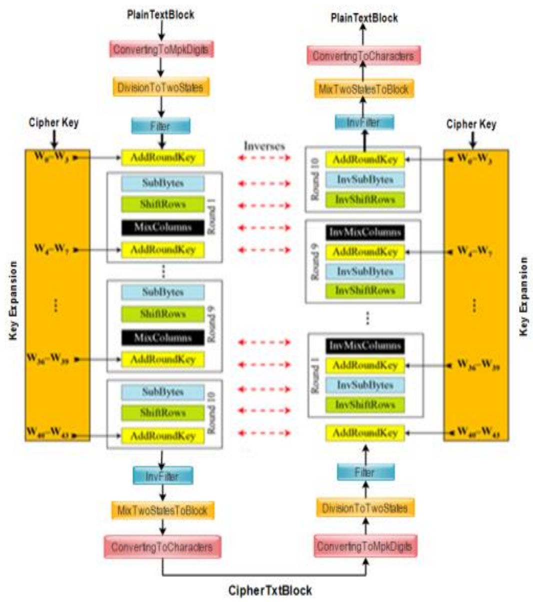


Fig. 1. Encryption and Decryption design

Key Expansion:

As shown in Fig. 1, a key expansion is used in encryption and decryption to create sub key for each round. AES_MPK algorithm likes the original AES algorithm where it uses a key expansion process. If the number of rounds is Nr, the key-expansion routine creates Nr + 1 128-bit round keys from one single 128-bit (16 byte) cipher key [13]. In addition, cipher key is converted to MPK digits (32 digits), then divided it to two blocks each block is 16 digits (i.e. the first block represents the first digits in 16 byte and the second block represents the second digits in 16 byte), and then make expansion on two block as follows:

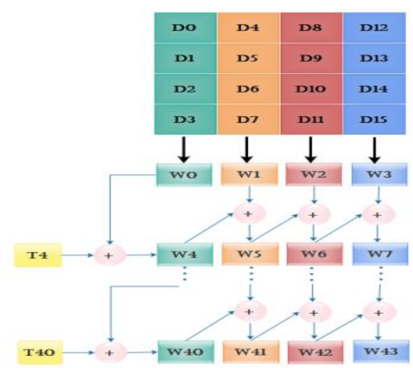


Fig. 2. Key Expansion

Fig. 2 shows each group of 4 bytes in the key being assigned to the first 4 words, then the calculation of the next 4 words based on the values of the previous 4 words, which is repeated several times to create all subkeys. Where Ti = RotateWord(SubWord(wi-1)), RotateWord performs a one-byte left circular rotation on the 4-byte word, and SubWord performs a byte substitution for each byte of the word as SubBytes function that is used in Encryption rounds.

Example:

Suppose the currently block is: "as programs grow" that is 16 byte and key is "test secret key!"

1) Make key expansion of key.

2) Convert block to MPK digits so becomes: "21 74 00 71 73 63 41 73 21 61 74 00 41 73 63 91"

3) Divide block to two states:

State 1 is $\begin{matrix} 2 & 7 & 2 & 4 \\ 7 & 6 & 6 & 7 \\ 0 & 4 & 7 & 6 \\ 7 & 7 & 0 & 9 \end{matrix}$ State 2 is $\begin{matrix} 1 & 3 & 1 & 1 \\ 4 & 3 & 1 & 3 \\ 0 & 1 & 4 & 3 \\ 1 & 3 & 0 & 1 \end{matrix}$

4) Apply filtering on the two states by replacing digits 9 and 8 with 7. In this case, the edition on only state1 because state 2 doesn't contain 9 or 8 digits.

5) Make pre round addition on the two states with two blocks of key.

6) **repeat**

7) Apply SubBytes, ShifRows, MixColumns, and AddRoundKey in two states.

8) **until** round nine.

9) Make SubBytes, ShifRows, AddRoundKey of last round on the produced two states that are produced from round nine.

10) Make InvFillter to return 9 or 8 digits to its location, the result is:

State1 is $\begin{matrix} 1 & 3 & 3 & 1 \\ 6 & 4 & 1 & 6 \\ 2 & 4 & 7 & 6 \\ 2 & 6 & 5 & 97 \end{matrix}$ State 2 is $\begin{matrix} 4 & 0 & 7 & 0 \\ 2 & 0 & 5 & 0 \\ 3 & 2 & 3 & 4 \\ 6 & 1 & 7 & 2 \end{matrix}$

11) Mix the two states to be one block
14 62 23 26 30 40 42 61 37 15 73 57 10 60 64 97 02

12) Covert block to characters by converting each two digits to character :
The cipher text of this block is: "-ncB?\hmF.rL)|6X0" .

13) Concatenate the currently cipher block with the previous cipher blocks.

B. *Merging Encryption and Steganography Algorithms*

The pseudo code of the proposed merged algorithm is as follows:

CRPTO_STEGNO Algorithm

Input: Secret Message M, Cipher Key K, Cover Image C.

Output: Stego Image S.

Steps:

1. M has been encrypted by using the AES_MPK that takes M and K then produces cipher text.
2. The cipher text has been hidden in C by using the method in [1] that is combining PVD-MPK method with MSLDIP-MPK method and then produces S.

The block diagram of the proposed merged method is shown in Fig. 3.

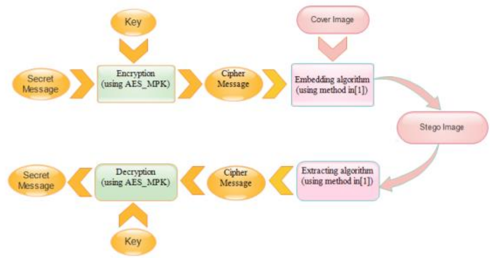


Fig. 3. Block Diagram of Proposed System

IV. Experimental Results and Discussions

A. *Experimental Environment:*

The used PC with windows 8 and equipped with a Genuine Intel(R) Core(TM) i5-4210U CPU 1.70 GHz 240 GHz with 8 GB RAM memory. MATLAB R2011b and Matlab code are used to implement the algorithm.

B. *Benchmarks:*

Several experiments with size 512 * 512 and 256 * 256 standard gray-scale images (Cameraman, Lena, Peppers, Lake, Airplane, and Baboon) were employed to embed a text encrypted message.

The message is firstly encrypted by AES-MPK algorithm, and then it is hidden by PVD-MSLDIP-MPK algorithm to be sent. At the receiver, the hidden message is extracted and then decrypted.

C. *Evaluation Parameters:*

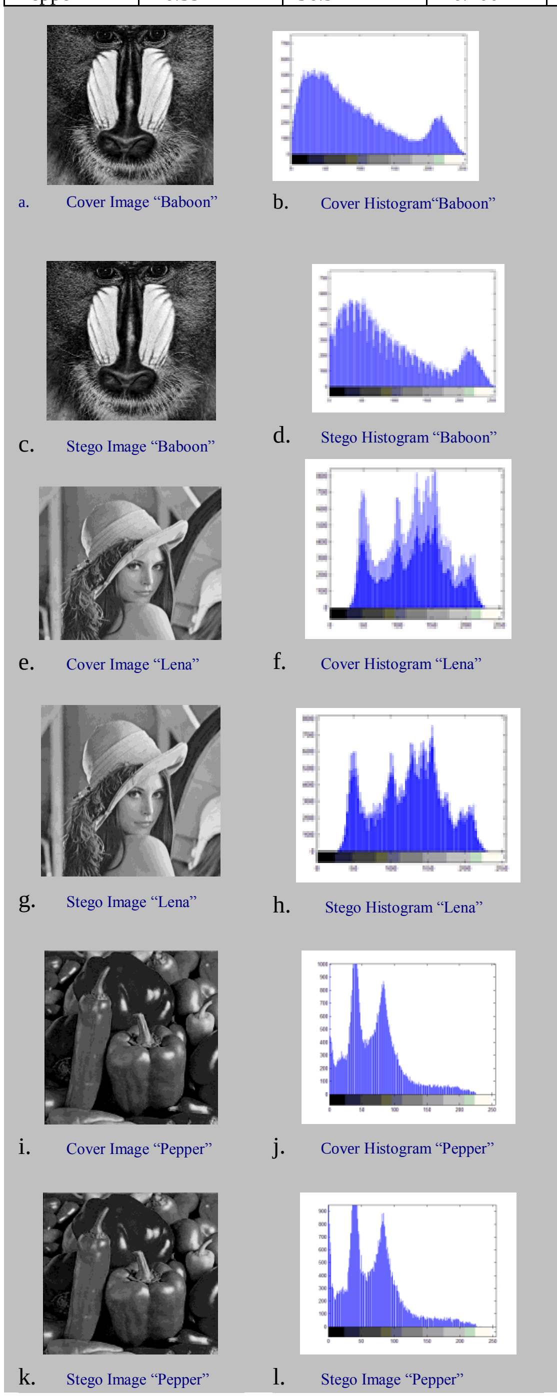
The performance of the proposed merged algorithm is evaluated by measuring imperceptibility (Stego-image quality), and payload (hiding capacity). Imperceptibility (Stego-image quality) measures how much difference (distortion) was caused by data hiding in the original cover, where the higher the stego-image quality, the more invisible the hidden message. The stego-image quality could be judged by using Peak Signal to Noise Ratio (PSNR) which determined by equation (2). If PSNR of gray scale image is larger than 36 dB then the human visual system (HVS) cannot distinguish between the cover image and the stego image [20].

Payload (Hiding Capacity) indicates how much data can be hidden within a cover image without making obvious distortion in the cover image quality. It is important to know that it has no meaning that an algorithm hides large amount of data and produces large distortion in image quality. So, it can say that a steganographic technique is an addition if it proves the increasing in payload while maintaining an acceptable visual quality of stego-image or improve the stego-image quality, at the same, hiding capacity level or if it can improve both [10].

The results that are obtained from these experiments are recorded and summarized in the table 1, table 2, table 3, and figure 4.

TABLE I. COMPARISON THE ALGORITHM IN [21] WITH THE PROPOSED ALGORITHM WITH DIV=19

Cover Image 256*256	Hiding Capacity (bytes)	PSNR of Method in [21]	Hiding Capacity (bytes)	PSNR of Proposed Method
Baboon	18.616	33.80	18.624	41.7875
Lena	13.003	43.56	13.008	44.9864
Pepper	16.394	36.91	16.400	43.6845



a. Cover Image "Baboon" b. Cover Histogram"Baboon"
c. Stego Image "Baboon" d. Stego Histogram "Baboon"
e. Cover Image "Lena" f. Cover Histogram "Lena"
g. Stego Image "Lena" h. Stego Histogram "Lena"
i. Cover Image "Pepper" j. Cover Histogram "Pepper"
k. Stego Image "Pepper" l. Stego Image "Pepper"

Fig. 4. Three cover images and output stego-images used in system simulation with their corresponding histogram

In table I, a comparison between the proposed merged method and method in [21] has been made by hiding (18.616, 13.003, and 16.394) secret bytes in 256 x256 cover images (Baboon, Lena, and Peppers) respectively. The results indicate that, the proposed method has higher PSNR values than method in [21], and also the PSNR values are much greater than 36 dB. This proves the suitability of the proposed method.

In figure 4, a comparison between the resulting stego images and their histograms with cover images and their histograms has been made. We can see that there is no significant change in stego histograms and visual quality of the resulting stego-image of the three images. Also, the change in histograms is influenced by the properties of image (i.e. the smooth area and edge area), so the larger number of edge areas in the original image, the more change in histogram of stego-image such as Baboon and Lena contrast to Pepper image. This is because the method that is used in hiding in smooth areas is MPK_PVD method.

TABLE II. COMPARISON OF PAPER [22] WITH THE PROPOSED METHOD WITH DIV=19

Cover Image 512x512	Hiding capacity (bytes)	PSNR of method in [22]	Hiding capacity (bytes)	PSNR of Proposed method
Baboon	57.043	39.2	63.408	42.8113
Boat	52.490	41.0	62.576	44.5444
Lake	52.662	41.5	62.672	44.0388
Lena	50.894	43.4	62.208	44.9678
Peppers	50.815	42.5	62.000	44.8326

In table II, a comparison between the proposed method and method in [22] has been made by hiding (63.408, 62.576, 62.672, 62.208, and 62.000) secret bytes in 512 x 512 cover images (Baboon, Boat, Lake, Lena, and Peppers) respectively. The results indicate that, the proposed method has higher PSNR values than method in [22], although more hiding capacity is used than that used by method in [22]. This proves the improved the stego-image quality and the hiding capacity, also the suitability of the proposed method.

TABLE III. LISTING OF COVER IMAGES AND SECRET MESSAGES WITH THE TIME REQUIRED TO ENCRYPT, HIDE, EXTRACT, AND DECRYPT OF SECRET MESSAGE

Cover Image		Secret Message (Bytes)	Time (Seconds)			
Name	*Size*		*Encrypt*	*Hide*	*Extract*	*Decrypt*
Lena	256*256	144	4.28	0.01	0.02	4.67
Pepper	256*256	416	12.31	0.03	0.04	13.72
Baboon	256*256	992	30.01	0.17	0.10	32.34
Camera man	512*512	1.744	50.43	0.09	0.19	55.96
Boat	512*512	2.720	81.42	0.15	0.29	89.01
Airplane	512*512	3440	101.1	0.17	0.49	106.3

V. CONCLUSIONS AND FUTURE WORK

In this paper, a new secure communication model has been presented that combines cryptography and steganography techniques to provide two layer of security, so the steganalyst can't reach to plaintext without knowing the secret key to decrypt the ciphertext. Firstly the secret data has been encrypted by using the AES_MPK then the encrypted data has been hidden in gray image by using PVD-MPK and MSLDIP-MPK methods. Due to this combination, the secret data can transmit over open channel because the cipher text does not look meaningless but its presence is concealed by using steganography for hiding cipher text in the images. Experimental results showed that our proposed model can be used to hide much more information than that other existed methods and the visual quality of the stego image is also improved, in addition to it is effective for secret data communication.

In the future work, we are looking forward to try applying the proposed method on audio and video. Also, we are looking forward to enhance the proposed method to make the capacity higher than it while keeping the same PSNR or higher.

REFERENCES

[1] M. E. Saleh, A. A. Aly, and F. A. Omara, "Enhancing Pixel Value Difference (PVD) Image Steganography by Using Mobile Phone Keypad (MPK) Coding, " International Journal of Computer Science and Security (IJCSS), Volume (9), Issue (2), pp. 397 - 397, 2015

[2] F. A. P. Petitcolas et al, "Information Hiding-A Survey," Proceedings of the IEEE, special issue on protection of multimedia content, Vol. 87, Issue. 7 PP. 1062-1078, July 1999.

[3] K. R. Babu et al, "A Survey on Cryptography and Steganography Methods for Information Security," International Journal of Computer Applications (0975 – 8887), Vol. 12, No.2, PP. 13-17, November 2010

[4] R. Oppliger, "SSL and TLS: Theory and Practice," ARTECH HOUSE, 2014.

[5] B. Schneier, "Applied Cryptography, Second Edition: Protocols, Algorthms, and Source Code in C (cloth)," pp. 1–1027, January 1996.

[6] K. Nitin K and N. Ashish V, "Comparison of Various Images Steganography Techniques," International Journal of Computer Science and Management Research, Vol 2, Issue 1, PP. 1213 – 1217, January 2013.

[7] S. Sharda and S. Budhiraja, "Image Steganography: A Review," International Journal of Emerging Technology and Advanced Engineering (IJETAE), Vol.4, Issue 1, PP. 707–710, January 2013.

[8] J. Raphael, and V. Sundaram, "Cryptography and Steganography – A Survey," International Journal, ISSN: 2229-6093, Vol 2 (3), PP. 626-630, 2011.

[9] A. J. Altaay et al, "An Introduction to Image Steganography Techniques," International Conference on Advanced Computer Science Applications and Technologies, PP. 122 - 126, 2012.

[10] L. M. Marvel et al "Spread Spectrum Image Steganography," IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 8, NO. 8, PP. 1075 - 1083 AUGUST 1999

[11] B. Zaidan, A. A. Zaidan, A.K. Al-Frajat and H.A. Jalab, "On the Differences between Hiding Information and Cryptography Techniques: An Overview", Journal of Applied Sciences 10(15), PP.1650-1655, 2010.

[12] A. Shoukat et al "A Survey about the Latest Trends and Research Issues of Cryptographic Elements," IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 3, No. 2, PP. 140-149, May 2011.

[13] J. Daemen, and V. Rijmen "AES Proposal: Rijndael," version 2, PP. 1-45, 1999, Available in http://csrc.nist.gov/archive/aes/rijndael/Rijndael-ammended.pdf#page=1.

[14] R. H. Sakr, F. Omara, and O. Nomir, "A COMPARATIVE STUDY OF SECURITY ALGORITHMS FOR CLOUD COMPUTING," International Journal of Intelligent Computing and Information Science, Vol.13, PP. 73-84, OCTOBER 2013.

[15] S. Murphy, "The Advanced Encryption Standard (AES)," information Security Technical Report, Vol. 4, No. 4, PP.12-17, 1999.

[16] I. A. Sada, "Hiding Data Using LSB-3", J.basrah researches (sciences), vol. 33. No. 4, pp. 81-88, Dec. 2007.

[17] M. Juneja, and P. S. Sandhu, "Designing of Robust Image Steganography Technique Based on LSB Insertion and Encryption," International Conference on Advances in Recent Technologies in Communication and Computing, PP. 302-305, 2009.

[18] Dutta et al, "New Data Hiding Algorithm in MATLAB using Encrypted secret message," International Conference on Communication Systems and Network Technologies, PP. 262-267, 2011.

[19] W. Stallings, "Cryptography and Network Security Principles and Practices, Fourth Edition," Prentice Hall, PP.1-663 November 16, 2005.

[20] R.O. El Safy, H. H. Zayed, and A. El Dessouki, "An adaptive steganography technique based on integer wavelet transform," ICNM International Conference on Networking and Media Convergence, PP. 111-117, (2009).

[21] H.B. Kekre, P. Halarnkar, and K. Dhamejani, "Capacity Increase for Information Hiding Using Maximum Edged Pixel Value Differencing," Springer-Verlag Berlin Heidelberg , PP. 190-194, 2011.

[22] J.-C. Joo, H.-Y. Lee, and H.-K. Lee, "Improved Steganographic Method Preserving Pixel- Value Differencing Histogram with Modulus Function", EURASIP Journal on Advances in Signal Processing, PP.1–13, 2010

Authenticating Sensitive Speech-Recitation in Distance-Learning Applications using Real-Time Audio Watermarking

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***Abstract*—Thispaper focuses on audio-watermarking authentication and integrity-protection within the context of the speech-data transmitted over the Internet in a real-time learning environment.The Arabic Quran recitation through distance learning is used as a case-study example that is characteristic of sensitive data requiring robust authentication and integrity measures. Thisworkproposes an approach for the purpose ofauthenticating and validatingaudio-data transmitted by a publisher or during communications between an instructor and students reciting via Internet communications.The watermarking approach proposed here is based on detection of the key patternswithin the audio signal as an input to the algorithm before the embedding phase is performed.The developed application could be easily used at both sides of the communication for ensuring authenticity and integrity of the transmitted speech signal and is proved effective for many distance-learning applications that require low-complexity processing in real-time.**

Keywords—Audio; Watermarking; Quran-recitation; Integrity; Authentication

I. Introduction

Recent advancements in information and communication technologies combined with the widespread growth of the Internet have enabled the ease of digital content distribution, communication and reproduction. Consequently, millions of users from the digital community are able to benefit from the advantages of fast and simple digital information exchange. However, such benefits come together in-hand with the problems and threats associated with ensuring digital copyright protection, preventing digital counterfeiting, proof-of-authentication and content-originality verification. Essentially, all such digital content in the Internet can be classified into images, text, audio and video, with the challenge being to ensure secure and reliable communications for each media type. In the literature, the techniques employed to provide the necessary security for such digital audio-content is known as digital-watermarking. Furthermore, cryptographic techniquesare commonly combined with the watermarking schemes in order to improve the security of the data within the communications channel.

The audio signals in their digital form are easily reproducible without any distortion; effective protection techniques have become essential. This need was reinforced by the new distribution supports such as the Internet and by compression methods such as MP-3 and MP-4 standards. Watermarking has been proposed to solve this problem. The watermark is a signal that is embedded into the original audio signal. The watermarked signal then contains information (hidden data that can be used for many purposes); for example, the hidden-data can be used to identify the owner (copyright protection to identify the source of illegal copies, verify the integrity of a document, track a signal in a network and include additional information such as the title, author, serial numbers, etc.Applications of digital audio watermarking are numerous and include: copyright protection, copy-protection, tamper proffering, access control, fingerprinting, digital right management, content authentication, annotation and privacy control, media forensics, communication enhancement, content protection, content filtering, improved auditing, content location, … etc. [1 - 2].

The constraints that should satisfy an audio watermarking scheme depend on the application. The main constraints are: 1) Inaudibility: the watermark signal must not be perceived by the listener, 2) Robustness: the watermark must resist any change in the signal, since this change does not result in degradation quality, 3) Capacity: the capacity corresponds to the quantity of bits to hide in the host signal, 4) Complexity: in practice, most watermarking operations must be done in real time (especially in the case of the watermark detection / extraction processes), this factor should be as low as possible by maintaining a high robustness. Hence, any watermarking scheme should find an ideal compromise between inaudibility, capacity, complexity, robustness and security which is not easy to achieve.

The audio watermarking techniques can be classified into two categories: spatial domain and frequency domain. The spatial domain is the classic process where the watermark embedding /extraction will take place directly on the signal values and does not require any transform processing. The frequency domain is the space in which the signal will be considered as a sum of frequencies of different amplitudes by applying some transforms such as Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Fast Fourier Transform (FFT), Singular Value Decomposition (SVD), etc. In this work, a technique based on DWT is proposed to identify the Quran reciter.

The objective of this work is to design and develop a digital audio-based encoding algorithm for sensitive speech (such as the Quran recitation case study used in this work) that embeds watermark data into the digital content whilst preserving the exact wordings, diacritics and Tajweed (quality of the pronunciation) sounds of the audio transmission.

The remainder of this paper is organized as follows: Section II provides the related work on audio-watermarking schemes and their classification. Section III provides the methodology and implementation for the proposed approach, and Section IV explains the integration of the various components and overall framework for the recognition system. Section V contains the analysis and results of the proposed framework, while Section VI provides a comparative study with other related works. Finally, Section VII concludes the paper.

II. Related Work

The research in audio watermarking started well after many techniques have been developed for watermarking on different multimedia files such as images and text. Embedding data in audio is usually more difficult compared to images since the Human Auditory System is more complicated than the Human visual system. Recently, many watermarking techniques have been developed to address different research problems related to audio files; however, techniques for highly-sensitive audio-content still need to be developed for sensitive applications such as the identification of recitations of the Holy Quran, in which even slight modifications to the audio-data can render the recitation/file as invalid [2]. The objective of this work is to develop an audio identification system for Quran reciters within the context of a distance-learning environment.

The patchwork technique first presented by Bender et al. [3]in 1996 was used on images. Statistical methods based on hypothesis testing had relied on large data sets. This method is usuallyapplied in a transform domain such as Fourier, Wavelet, ,… etc. to spread the watermarking in the time domain in order to increase robustness against any modifications [3-5].

Yee and Wei, implemented a non-blind two-channel time-frequency digital bits audio watermarking scheme with error-correcting code. The watermark bits are encoded with cyclic code before embedding it into the audio signal using time-frequency compression expansion technique with psychoacoustic model which decides on the coefficients to be deleted or added. Both channels of the stereo audio signal are used for watermark embedding. This combination of cyclic code and two-channel approach using the robust time-frequency technique of coding watermark bits has resulted in perfect recovery of watermark under attacks [6].

The work of Zhang et al. [7] dealt with the implementation of real-time audio watermarking techniques based on Digital Signal Processing (DSP). The implementation was illustrated using DSK5402.It uses qualitative watermark methods and fast Modulated Complex Lapped Transform(MCLT). The experimental results show the robustness and transparency of this technique [7]. Other works based on different transforms such as: Gao et al. in [8] proposes an audio zero-watermarking algorithm based on FFT. The proposed algorithm provided a solution for the contradictions of imperceptibility and robustness.The algorithm shows effective resistance to different types of attacks and appears to meet the requirements of watermarking security.Xiong-hua and Wei-zhen [9], proposed an adaptive digital audio blind detection fragile watermarking algorithm based on a modified Discrete Fourier Transform (DFT) transform.

The work developed by Furon and Pierre proposes an asymmetric watermarking method which provides higher security level against malicious attacks used for copy protection purposes.This method is versatile, as it can be adapted to a large number of watermarking techniques based on Direct Sequence Spread Spectrum (DSSS). The method studied was applied to copy protection framework by analyzing the possible threats and estimating the complexity of each class of attacks.The proposed method shows that watermarked content only attack is not possible with this method which is seen to be a real threat to other techniques such as DSSS and Watermarking Costa's Schemes(WCS). The disadvantages of this method are that asymmetric detectors need more complexity, memory and accumulate large amount of content in order to make a reliable decision [10].

The work by Tavakoli proposes a watermarking technique for cover communication through the telephone system.This technique is suitable for theIntegrated Services Digital Network(ISDN) and the Public Switched Telephone Network(PSTN) networks that can be modified for mobile systems. It uses a direct sequence spread spectrum algorithm with perceptual modeling of the Human Auditory System for embedding watermark into audio signals.Experimental results show the watermark is robust against attacks such as, Additive White Gaussian Noise(AWGN), Low Pass Filtering (LPF), D/A and A/D conversion, A-Law or u-Law conversion and down sampling to 64 kbps. In addition, it is also robust against audio format conversions such as wave to mp3 [11].

The authors in [12] proposed an audio watermarking technique based on chaotic mapping and used DWT to extract the wavelet coefficients of the audio signal. Here, the detail wavelet domain is chosen to embed the watermark so that to achieve transparency and fragility; Principle Component Analysis(PCA) was used to help reduce the watermark information needed to be embedded. Therefore, the signal reconstruction was achieved by the extracted watermark and can accurately locate the tampered region in the time domain. The experimental results demonstrate the efficiency of the proposed method in terms of fragility, transparency and tamper localization.

Dutta et al. proposed an audio watermarking method based on Biometrics, in which the biometric pattern of an iris is used to generate the watermark that has a stamp of ownership. The watermark is then embedded in the high-energy regions selectively, which makes the embedding process robust against cropping and synchronization attacks [13].

In Chen et al. [14], a fragile watermarking scheme was proposed that embeds watermark data into the principle-components of the detailed wavelet coefficients with blind extraction based on the fast independent component-analysis system. The proposed fragile authentication scheme had demonstrated excellent transparency and tamper-detection capabilities under a number of simulated attack-scenarios.

Zhao and Shen [15] presented a semi-fragile audio watermark algorithm for authentication that includes tamper detection capabilities. The experimental results had also confirmed its robustness against various signal-processing operations. The contribution in [16] describes an inaudible speech and watermarking algorithm which embeds copyright information into audio files as proof of ownership. In this study, the watermarking process was achieved using a cascade of the SVD and DWT transforms. A set of attack scenarios specified by the Stirmark benchmark for audio files were simulated. It was demonstrated that the embedding logo could be successfully extracted whilst remaining robust against most attacks being simulated.

Baranwal and Datta, presented a comparative study of spread spectrum based audio watermarking techniques [17]. Er and Gul [18] presented a comparison of audio watermark techniques that can be used for source-origin authentication in real-time session initiation protocol (SIP) such as, Voice over IP (VoIP). The least significant-bit (LSB), DC-level shift (DCSHIFT), frequency-hopping spread spectrum (FHSS) andDSSS approaches were compared in terms of robustness and evaluation-times, complexity and capacity metrics. The results demonstrated the effectiveness of the FHSS and DSSS schemes for VoIPapplications that require source-authentication.

Other recent works found in literature include: The work of Kang et al. whoproposed a multi-bit spread-spectrum audio watermarking technique based on geometric invariant log coordinate mapping feature [19]. Chen et al. proposed an optimization based audio watermarking technique based on DWT [20]. Wang and Zhao proposed a synchronized invariant audio watermarking scheme based on DWT and DCT [21], Petrovic and Yang developed an audio watermarking in the compressed domain [22]. Zhao and Shen developed an audio watermarking algorithm for audio authentication [23]. Al-Haj et al. proposed a hybrid DWT-SVD audio watermarking [24].For further details on some of the above techniques or others the reader may refer to the following surveys published on this topic: [1], [25 – 27].

In an attempt to classify audio watermarking techniques found in literature, but not limited to [1 – 27], the authors developed the classification tree, Figure 1, of potential Audio-Speech Watermarking Techniques considered for the Holy Quran. Table 1 provides the general classification of audio watermarking techniques with their applicability to Quran computing.In addition, it provides the limitations and considerations needed.Finally, from studying the methods available in the literature, Figure 2 provides an overview of key issues of particular importance in Audio-Watermarking for Quran recitations.

TABLE I. AUDIO WATERMARKING TECHNIQUES APPLICABLE TO QURAN COMPUTING (SUMMARIZED FROM [2])

Application Domain	Technique	Applicable to Quran IT	Limitations and Considerations
Audio-Based Watermarking	Time-domain techniques	Not Ideal	Modifies fine details in recitation/speech; poor robustness to attacks
	Transform-domain techniques	Yes-conditional	Effective when used with spread-spectrum approach, provides good robustness. Ensure high inaudibility and no distortion.
	Spread-Spectrum Techniques	Yes-conditional	Embedding may exploit those less active segments during recitation for minimum distortion; good robustness to attacks.

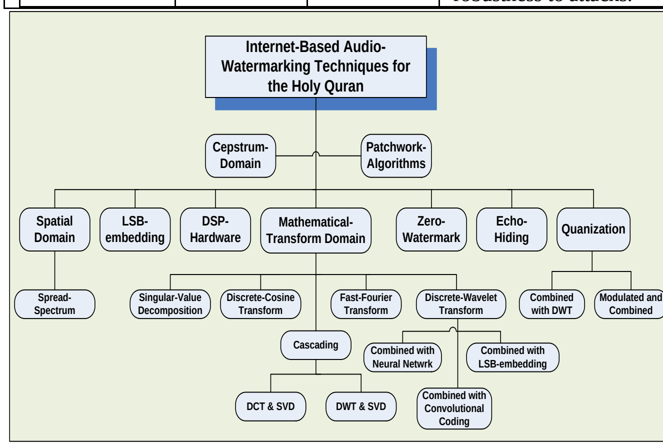

Fig. 1. Classification of potential Audio-Speech Watermarking Techniques for the Holy Quran

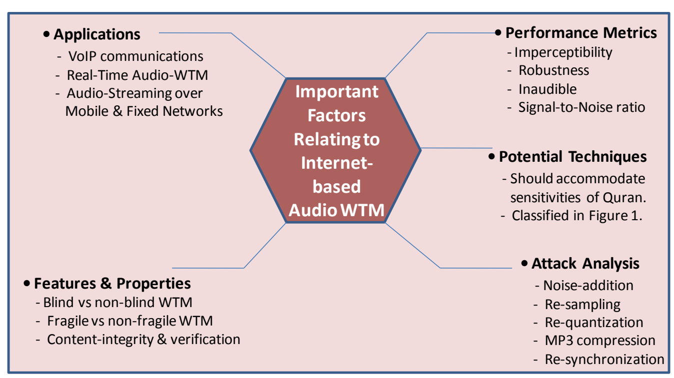

Fig. 2. Factors related to Internet-based audio Watermarking

In this work, the problem being addressed isthat of the security aspect of integrity and authentication with regard todigital Quran recitations and audio resources. Hence, a critical requirement is to ensure that all digital Quran audio/content that had originated from a known reference or reciter would be secure from being tampered with or modified in any way. That is, any modification or tampering of the digital Quran audio signal by an original publisher or source-recitation would be easily detected by the detection software and rendered as an invalid signal.The proposed methodology is provided in the next section.

III. METHODOLOGY AND IMPLEMENTATION

The proposed work involves identifying the Holy Quran reciter by providing an improvedapproach based on DWTfor one level to achieve very low complexity (low watermark size). The frequency domain based research works in the literature deals with copyright issues and individual/public property. It should be noted that the audio watermarking approach based on transforms such as FFT, DCT, DWT,SVD, etc., provide remarkable robustness, but unfortunately are associated with high complexity which makes it difficult to adapt for real time applications. In contrast, the results obtained in our approach were remarkable in terms of robustness and complexity. We explain our improvement through three implementation approaches considered in this work, which include: (i) the embedding and extraction process for the case of enhanced robustness in section A, (ii) the approach of enhanced robustness and security by applying the Rivest, Shamir, Adleman (RSA) algorithm on the watermark as in section B, and finally, (iii) the approach for enhanced robustness with the use of secure Hyper Text Transfer Protocol (HTTPS), which employs the secure-socket layer (SSL) technique (section C). The use of security measures in section B and C significantly helps to preserve the outstanding safety against falsification of the reciter identity. However, due to the need for avoiding high processing-complexity and running-times, the RSA-based encryption/decryption approach (section B) was then replaced with the use of HTTPS, and SSL (section C) in order to achieve reduced online complexity for real-time applications.

A. Encoding Based on Robustness Requirement Only

In this section, we describe the first of three implementation approaches considered in which only the robustness metric is considered in the embedding scheme prior to signal transmission from the user-end. The mathematic and algorithmic steps involved in the embedding and extraction schemes are detailed in section A.1 and A.2, respectively.

1) Watermark Embedding Scheme

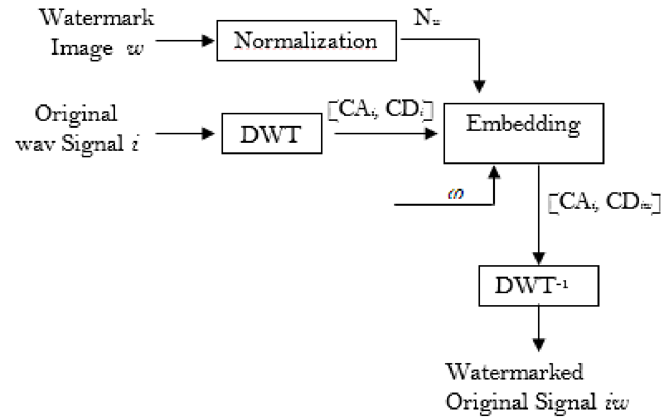

Fig. 3. Linear Interpolation-Based Watermarking Embedding Scheme

The linear interpolation based watermarking embedding process from Figure 3is defined as:

$$i_w^{(p,q)} = (1-\varphi)w^{(p,q)} + \varphi i^{(p,q)}$$

where:

$i_w^{(p,q)}$ is the watermarked original audio signal

$w^{(p,q)}$ is the used watermark

$i^{(p,q)}$ is the original audio signal

(p, q) is the position of the sampled point

φ is the watermarking key, $\varphi \in]0,1[$

CA: is the audio-segment with the most important information (from the input signal)

CD: are the detailed-segments within the input audio-signal (embedding is applied on this segment).

CD_{iw} is the embedded signal

Normalization: is the process of transforming the input matrix into a linear-vector.

In linear interpolation based watermarking, two cases will be analysed:

Case1: audible watermarking

When: $\varphi \to \mathbf{0}$ means $i_w^{(p,q)} \cong w^{(p,q)}$

Case2: inaudible watermarking

When: $\varphi \to \mathbf{1}$ means $i_w^{(p,q)} \cong i^{(p,q)}$

Since the embedding process will only concern the CD_icomponent, we have:

$$CD_{iw}^{(p,q)} = (1-\varphi)N_w^{(1,k)} + CD_i^{(p,q)}$$

Where:

$$N_w^{(1,k)} = \frac{w^{(S1,S2)}}{255}$$

s_1, s_2 are the size of the watermark image w

k is the length of the normalized watermark image $N_w^{(1,k)}$

Hence, after applying the wavelet inverse on the components $\left(CD_{iw}^{(p,q)}, CD_i^{(p,q)}\right)$ as follows, we will obtain the audible watermarked original audio-signal $i_w^{(p,q)}$:

$$i_w^{(p,q)} = DWT^{-1}\left(CD_{iw}^{(p,q)}, CD_i^{(p,q)}\right)$$

Algorithmic Steps:

1. Read the original wav signal *i*.
2. Compute the wavelet components of *i* (CA*i*, CD*i*)
3. Create a watermark image *w* (representing the reciter name)
4. Normalize *w* and obtain N*w* (where N*w*=*w*/255)
5. Perform the watermark embedding: CD_{iw}=(1-t)N_w+tCD_i
6. Apply the wavelet inverse (DWT^{-1}) to obtain *iw* (the watermarked original signal), which is sent over the SSL transmission line.

2) Watermark Extracting Scheme

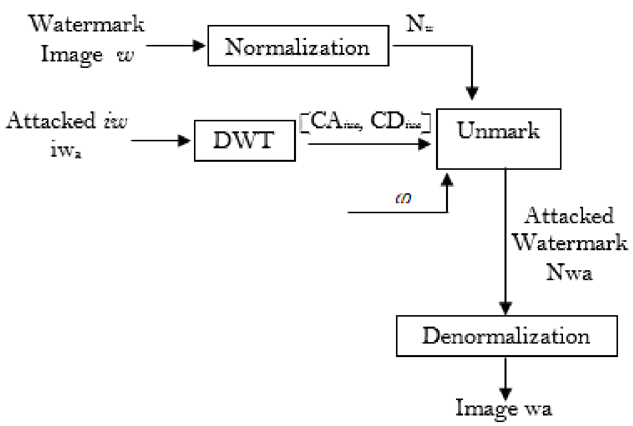

Fig. 4. Linear Interpolation-based watermarking embedding scheme

The extraction process, Figure 4,is defined by:

$$w_a^{(p,q)} = \frac{1}{\varphi} CD_{iwa}^{(p,q)} - \frac{1-\varphi}{\varphi} w^{(p,q)}$$

Where:

$N_{wa}^{(p,q)}$ is the extracted normalized watermark after an attack

$CD_{iwa}$is the extracted watermark following an attack during transmission

$CD_{iwa}^{(p,q)}$ is the attacked component $CD_{iw}^{(p,q)}$

To obtain the attacked watermark image, we must denormalize the vector $N_w^{(1,k)}$ by:

$$w_a = N_w^{(1,k)} \times 255$$

Algorithmic Steps:

1. Read the attacked signal *(iw$_a$)*, derived from the original-signal (*iw*) following an attack.
2. Compute the wavelet components of iw_a (CAiw_a, CDiw_a)
3. Read the watermark image *w* (e.g. a text-string or bit-stream of the reciter's name)
4. Normalize *w* and obtain N*w* (where N*w*=*w*/255)
5. Perform watermark extraction by: Nw_a=1/(1-t) CDiw_a – (t/1-t)N*w*
6. DenormalizeNw_a to obtain w_a, such as w_a= Nw_a *255

B. Encoding Based on Robustness and Security (RSA Encryption)

In this section, we describe the second implementation approach developed, in which the robust embedding scheme follows with RSA encryption prior to signal transmission from the user-end in order to ensure robust and secure transmission. The mathematic and algorithmic steps involved in the embedding and extraction schemes are detailed in section B.1 and B.2, respectively.

1) Watermark Embedding Scheme

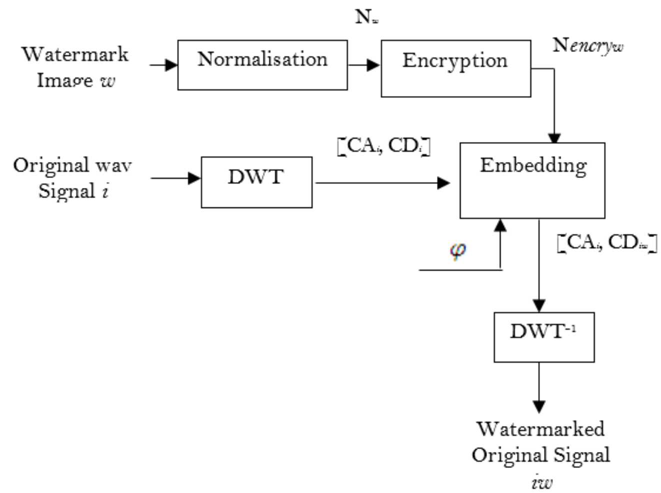

Fig. 5. Encoding Scheme based on Robustness and Security

The algorithmic steps for embedding and encryption are summarized as follows:

Algorithm steps:

1. Read the original wav signal *i*.
2. Compute the wavelet components of *i* (CA*i*, CD*i*)
3. Create a watermark image *w* (representing the reciter name)
4. Normalize *w* and obtain N*w* (where N*w*=*w*/255)
5. Encrypt N*w* (based on RSA Algorithm) and obtain $Nencry_w$following encryption.

6. Achieve the watermark embedding by: CD_{iw}=(1-t) $Nencry_w$ +tCD_i
7. Apply the wavelet inverse (DWT^{-1}) to obtain *iw* (the watermarked original-signal).

2) Watermark Extraction Scheme

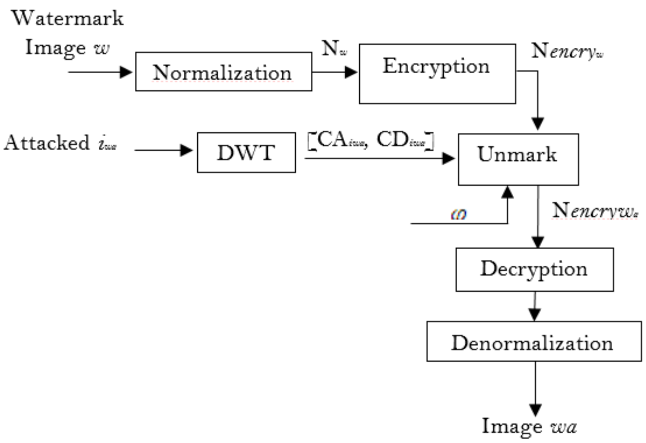

Fig. 6. Extraction Scheme based on Robustness and Security

The algorithmic steps for extracting an RSA-encrypted signal are summarized as follows:

Algorithm steps:

1. Read the attacked signal *(iw_a)*, derived from the original-signal (*iw*) following an attack.
2. Compute the wavelet components of iw_a ($CAiw_a$, $CDiw_a$)
3. Read the watermark image *w* (e.g. the reciter name as a bit-stream/text-string)
4. Normalize *w* and obtain N*w* (where N*w*=*w*/255)
5. Encrypt N*w* (based on the RSA Algorithm) and obtain $Nencry_w$
6. Perform watermark extraction using: $Nencry_{wa}$ =1/(1-t) $CDiw_a$ –(t/1-t) $Nencry_w$
7. Decrypt $Nencry_{wa}$ and denormalize it to obtain w_a

C. Enhanced Security Mechanism For Real-Time Support by Combining Robust Watermarking with HTTPS/SSL

This section describes the third implementation approach developed, in which the robust embedding scheme follows with transmission from the user-end using HTTPS and SSL in order to ensure robust and secure transmission with lower complexity as compared with the RSA approach (from section B).

To enforce the security of the watermarked *.wav* signal and also the authenticity of the reciter, it was decided to assign a session-based protocol to each reciter, identified using the username and password followed by a user-verification code sent to the user's email. This was the first layer of security used in this work and was used in order to prevent (internal) attacks/non-authentic access from the client-side. The second layer of security used was to secure all data transmitted on the network from external attacks. As previously mentioned, the RSA algorithm was initially considered and applied to provide the required encryption. However, the RSA encryption scheme was then replaced using the HTTPS protocol, using SSL libraries in order to provide a lightweight security scheme that creates a secure session between the client and the server before proceeding with the audio transmission. The main advantage of this alternative security-mechanism is that it is able to secure the transmitted audio-signal using a lightweight secure-socket layer (SSL) approach that is more suitable for real-time requirements since the RSA-based approach (section B) proved to be too complex when encrypting the whole signal to be transmitted or even when encrypting the watermark-signal only.

IV. Proposed Quran Recitation Recognition Framework

The proposed Quran recitation recognition framework is shown in Figure 7, and comprises of two main parts; the encoder at the sender-side and the decoder at the receiver-side. Biometric fingerprints were simulated using textual bit-streams of the user's name for demonstration of the initial prototype. In reality the text-string would be replaced by a bit-string of the fingerprint applied by the client.

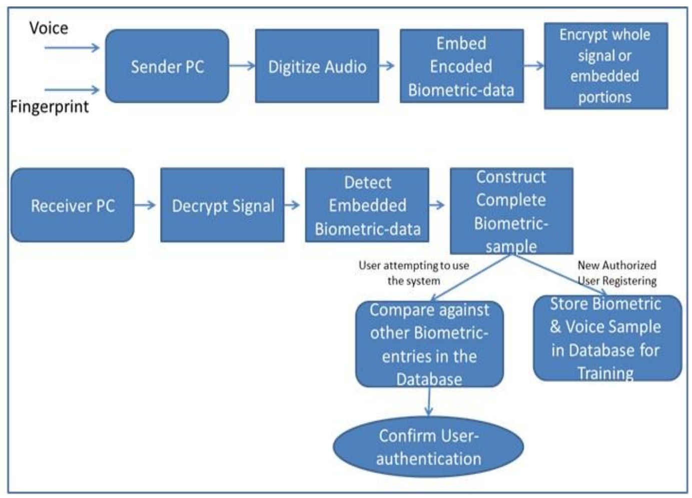

Fig. 7. Framework Diagram of Functional Blocks at the Sender and Receiver

The encoding part is at the sender's side where we have voice input by a given student (reciter) and at the same time we have a database for all students in the course where a fingerprint/watermark is stored for each student/trainer. The fingerprint could be any type of user-specific signal/signature from a biometric database (or a new biometric signature), which is also input into the application. In Figure 7, the input voice-signal is initially in analog format and has active and inactive periods whereby the signal is sampled and quantized into a digital signal. Embedding in done on the central region of the detail-components (e.g. the *CD* component from section III) of the signal, whilst avoiding the most important information-components (e.g. the *CA* component from section III) that contains the main recitation signal components. The process of watermark embedding is illustrated in section V. Following the embedding phase, the Quran-signal would not be altered, since due to its sensitivity requirement, a small change would render the signal as invalid. On the other hand, the experiments showed that the embedded watermark had resulted with low noise effect without altering any fundamental characters, Tajweed or diacritic pronunciations in the Quran recitation (which are mainly found in the unaltered *CA* components). Additionally, the encoded-signal may undergo security operations as described in section III.B and section III.C, for the case of the RSA and HTTPS/SSL approaches, respectively. This work initially considered and applied the RSA cryptographic algorithm, which was then replaced by the HTTPS approach with SSL in order to avoid the high complexity and long processing delays for the RSA algorithm to encrypt and decrypt the audio-signal. Through our experiments, the SSL approach was found to be significantly better than the RSA algorithm for real-time audio-streaming applications due to the lower complexity when using SSL. Figure 8 summarizes the stages of data-flow at the sender's side prior to transmission.

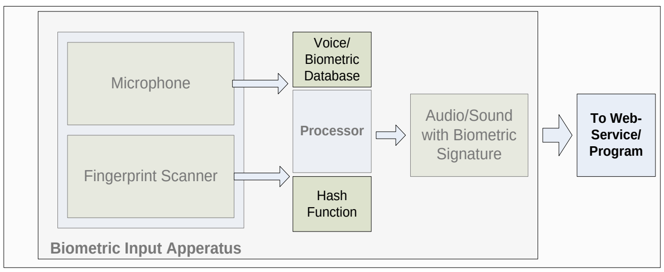

Fig. 8. Detailed Analysis of Data-Flow at the Senders-Side

At the receiver's side, when this information is received, the decoding process is completed by going through the following steps: decrypting the signal (optional; as in the case when RSA was used), identifying the watermark portions in the signal, extracting the watermark to generate the original watermark code, then comparing this watermark to the stored watermark in the database: if there is a match, then the reciter is successfully identified and validated in the system, or otherwise discarded as invalid. In the case of a new reciter, the new signature/watermark is stored, verified by the receiver-institution and usable thereafter. The principle system architecture diagram, combining all functional components at the sender and receiver sides is now summarized in Figure 9.

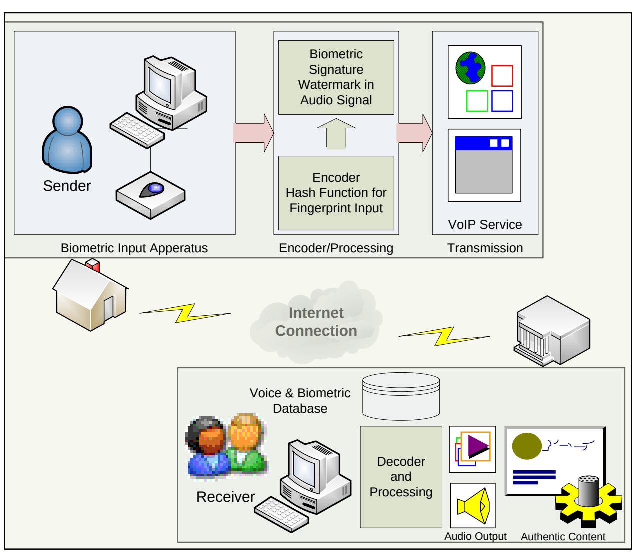

Fig. 9. Principle System Architecture Diagram

V. Analysis and Results

The example of the watermark embedding/extracting processis illustrated as follows:

1) Reading the original wave signal i,Figure 10.

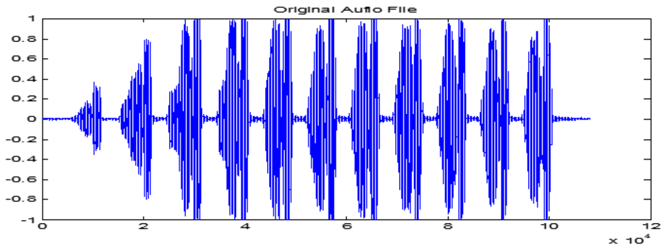

Fig. 10. Original Audio File

2) Calculate the wavelets coefficients of i (CAi and CDi) on one level, Figure 11.

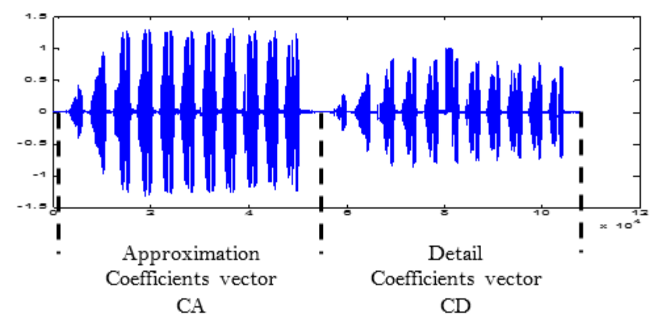

Fig. 11. Calculate the wavelets coefficients of *i* (CA*i* and CD*i*) on one level

3) Embedding the normalized watermark in CD coefficients of the signal i by the watermark w in the center of CDi, Figure 12.

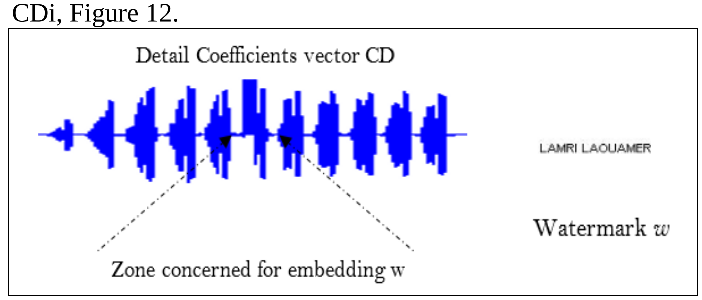

Fig. 12. Embedding the normalized watermark in CD coefficients

4) Obtaining the watermarked signal iw, Figure 13.

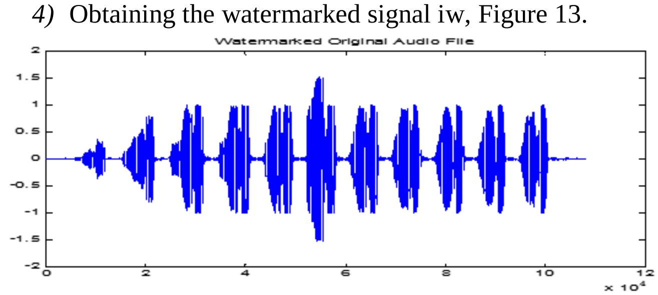

Fig. 13. Finding the watermarked Signal,*iw*

For demonstration purposes, the RSA-approach will be illustrated when being applied on the watermark. Here, the security will be checked and the embedding/extracting processes will concern the encrypted watermark and not the watermark itself. An example of encrypting and decrypting the normalized watermark is shown in Figure 14.

Fig. 14. Illustration of RSA-based Encryption and Decryption on the Watermarked-Signal

A website was developed which consists of two-tier architecture as follows:-

1) The client-end can access the application through any web-browser (e.g. Internet Explorer, Mozilla, Chrome, etc. ....).

2) The server-end is where the whole application is accessed.

- PHP programming language was used for developing basic services in the developed application, such as the uploading function.
- HTTPS protocol was used for securing all communications between the client-side and server-side.
- The operations of the watermark embedding, extraction and the checking of possible attacks on the watermarked signal were achieved using three Matlab programs.

These three programs have been used as executable files within our PHP web page. These programs are the core of this proposed audio prototype. The complexity of our scheme is polynomial, which makes our approach realizable with acceptable running-time performance. It remains to note that the checking tasks have worked as required with an accuracy rate of 100%.

The client/server prototype provides the user with the choice either focusing only on robustness (watermark embedding and extracting) or either to introduce the security aspect (encrypted watermark embedding and extracting) as an additional requirement during communications. The prototype essentially requires download and installation on a server-machine, which can be accessed for transmitting audio from the client side and receiving audio at the instructor-side. Hence, the sender and receiver both access the same application/interface; however, have different uses and access-privileges. Figure15 illustrates a snapshot of the application.Steps to use the application include: first, the client records the recitation, then the reciter embeds the recitation, following this the reciter submits the recorded recitation and sends the results.Finally, the audio-signal is encrypted and watermarked ready for transmission to the instructor/receiver-side.

Fig. 15. Audio signal – Watermarking and Encryption

The receiver side operation proceeds with login as an admin i.e.Quran-instructor/evaluator, who is presented with the updated recitations received.

VI. Comparison with the State of the Art Audio Watermarking Literature

The scheme presented in this approach provides a number of practical advantagesand enhancements compared to some other existing schemes and can be summarized as follows:

- First, the proposed approachonly requires embedding little information(e.g. only a few data-bits to hide),thereby offering good capacityin terms of complexity representing therecite data,and is adaptable for the identification processas required in real time applications.

- Second, the *detailed* coefficients vector in wavelet transformwere exploitedduring the watermarking process, since it had resulted with no considerable alteration to the quality of the audible sound.Hence, one further enhancement to existing approaches in the literature was that all embedded data was completely encoded into the *detailed* coefficients vectors. In contrast,modifying the *approximation*coefficients vector in the wavelet transform(as done in other schemes) had a directly impact on the signal quality.

- Third, the proposed approachwas found to bemore robust against various attacks applied as compared to other related works in [23] and [28].

- A secure process is achieved in the proposed scheme thatconfirms the identification of the reciter and detects any false/unauthenticreciters.

- Finally, it is worth noting that the use of the improved audio-watermarking scheme proposed here for application in highly-sensitive Quran voice-signals (and thus the constraints consequently imposed on the embedding scheme) is itself novel and not found anywhere in the related literature.

Many works found in the audio-watermarking literature have focused onrobustness and inaudibility/capacity performance for various approaches using either the Stirmark Benchmark attacks or self-simulated attack scenarios by simulation after varying a number of influential parameters. In this study, we present our results in comparison with two other closely-related studies after matching the attack-scenarios, types and parameter-values used in the other studies (Table 2). The results obtained from our approach were found to be better than the results presented in [23] in terms of the normalized correlation coefficients (NCs), since all used NC-values were closer to 1 as compared with [23]. Furthermore, the proposed approach provides highly significant results in terms of Bit Error Rate (BER) values, which are close to 0 inalmost all attack scenarios. This suggests that the proposed approach is more robust against the attacks considered in the tests when compared to the results obtained in [28] (Table 2).

TABLE II. COMPARATIVE RESULTS AGAINST RELATED WORK UNDER SIMILAR SIMULATION PARAMETERS

Normalized Correlation Coefficient NC		
	Our approach	Proposed approach in [23]
Resamp22050	0.9832	0.9401
Re-quan	0.9956	0.9934
AWGN	0.9607	0.885
Low pass	0.9813	0.9318
MP3- 48kb	0.972	0.9279
MP3-64kb	0.983	0.9363
MP3-96	-	-
MP3-128kb	-	-
Bit Error Ratio BER		
	Our approach	Proposed approach in [28]
Resamp22050	0	0
Re-quan	0.56	1.25
AWGN	0.82	5.6
Low pass	0.93	7
MP3- 48kb	0.75	17
MP3-64kb	0.3	8
MP3-96	0.1999	3.7
MP3-128kb	0.171	3.7

VII. CONCLUSION

The authentication scheme presented in this work provided a robust, secure and practical approach in terms of achieving low complexity as required for ensuring real-time authenticity of sensitive-speech data. Arabic Quran recitations were taken as a case study during experimentations due to the sensitive nature of the recitation, which had resulted with additional complexities to overcome, in contrast to ordinary speech-data mainly addressed in the literature. The main novelty in this work was found in our application and enhancement of existing audio-watermarking techniques under the constraints of the sensitive voice data, which should not be altered, with the further requirement that any embedded data remain inaudible. Themechanism executes a number of functional stages at the sender and receiver sides and avoids distortion of the intelligible and audible Quran input-signal, and had therefore successfully addressed the sensitivities of the digital-Quran audio-signal. Following experiments with several protocol variations, our final solution had employed the DWTthrough an HTTPS protocol in order to achieve reduced complexity and online authentication in real-time. Notably, our contribution compared very well with the other related approaches in the literature and had provided enhanced results for our key metrics of interest that had included robustness, inaudibility and capacity, enabling us to achieve real-time authentication.

The Quran recitation recognition framework and prototype produced in this work facilitates Quran Learning Institutions to authenticate the student-identity/reciter over an unreliable network, such as the Internet in cases where remote/distance-learning is required. The work in this paper is also very useful for student-evaluation purposes in a distance-learning environment, particularly where certificates are issued by an institution following student/client-verification. The prototype was successfully tested and was able to confirm authentic and non-authentic client identities. Finally, such a system could also be employed for more general verification purposes or other similar online-based learning centers/institutions requiring user voice-authentication before issuing academic or other certificates.

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REFERENCES

[1] Singh, Prabhishek, and R. S. Chadha. "A Survey of Digital Watermarking Techniques, Applications and Attacks." International Journal of Engineering and Innovative Technology (IJEIT) 2, no. 9 (2013).

[2] Tayan, O.; Alginahi, Y.M., "A review of recent advances on multimedia watermarking security and design implications for digital Quran

computing," Biometrics and Security Technologies (ISBAST), 2014 International Symposium on , vol., no., pp.304,309, 26-27 Aug. 2014

[3] Bender, Walter, et al. "Techniques for data hiding." IBM systems journal 35.3.4 (1996): 313-336.

[4] Yeo, In-Kwon, and HyoungJoong Kim. "Modified patchwork algorithm: A novel audio watermarking scheme." Speech and Audio Processing, IEEE Transactions on 11, no. 4 (2003): 381-386.

[5] Cvejic, Nedeljko, and TapioSeppanen. "Robust audio watermarking in wavelet domain using frequency hopping and patchwork method." In Image and Signal Processing and Analysis, 2003. ISPA 2003. Proceedings of the 3rd International Symposium on, vol. 1, pp. 251-255. IEEE, 2003.

[6] HtayHtay Yee; Foo Say Wei, "Audio watermarking with error-correcting code," TENCON 2009 - 2009 IEEE Region 10 Conference, vol., no., pp.1,5, 23-26 Jan. 2009

[7] Qiuyu Zhang; Jiabin Deng; Zhanting Yuan, "Implementation of Real-Time Audio Watermarking Based on DSP," Intelligent Information Technology Application Workshops, 2009. IITAW '09. Third International Symposium on , vol., no., pp.145,148, 21-22 Nov. 2009

[8] Liting Gao; Wei Zhao; Xiumei Wen; Lixia Wang, "An audio zero-watermarking algorithm based on FFT," Networking and Digital Society (ICNDS), 2010 2nd International Conference on , vol.1, no., pp.274,277, 30-31 May 2010.

[9] Huang Xiong-hua; Jiang Wei-zhen, An adaptive fragile audio watermarking based on MDFT, International Conference on Intelligent Computing and Integrated Systems (ICISS), 2010.

[10] Furon, Teddy, and Pierre Duhamel. "An asymmetric watermarking method."Signal Processing, IEEE Transactions on 51, no. 4 (2003): 981-995.

[11] Tavakoli, E.; Vahdat, B.V.; Shamsollahi, M.B.; Sameni, R., Audio Watermarking for Covert Communication through Telephone System, IEEE International Symposium on Signal Processing and Information Technology, 2006.

[12] Ning Chen; Meng-yao Zhu; Sen Liu, "A new fragile audio watermarking scheme," Audio Language and Image Processing (ICALIP), 2010 International Conference on , vol., no., pp.367,372, 23-25 Nov. 2010

[13] M. K. Dutta, P. Gupta, V.K. Pathak, "Biometric Based Watermarking in Audio Signals", proceedings of the International Conference on Multimedia Information Networking and Security, 2009.

[14] N. Chen, M-Y. Zhu, S. Liu, "A New Fragile Audio Watermarking Scheme", International Conference on Audio Language and Image Processing, China, 2010

[15] H.Zhao, D. Shen, "An Audio Watermarking Algorithm for Audio Authentication", 2010.

[16] M. A. Nematollahi, S.A.R. Al-Haddad, S. Doraisamy, M. I. Bin Saripan, "Digital Audio and Speech Watermarking Based on the Multiple Discrete Wavelets Transform and Singular Value Decomposition", proceedings of the Sixth Asia Modelling Symposium, 2012.

[17] N. Baranwal, K. Datta, "Comparative Study of Spread Spectrum Based Audio Watermarking Techniques", IEEE-International Conference on Recent Trends in Inforrmation Technology, Chennai, India, 3-5 June, 2011.

[18] F. Citak Er, E. Gul, "Comparison of Digital Audio Watermarking Techniques for the Security of VOIPCommunications", 2011.

[19] Xiangui Kang; Rui Yang; Jiwu Huang, "Geometric Invariant Audio Watermarking Based on an LCM Feature," *Multimedia, IEEE Transactions on* , vol.13, no.2, pp.181,190, April 2011

[20] Chen, S.-T.; Wu, G.-D.; Huang, H.-N., "Wavelet-domain audio watermarking scheme using optimisation-based quantisation," *Signal Processing, IET* , vol.4, no.6, pp.720,727, Dec. 2010

[21] Xiang-Yang Wang; Hong Zhao, A Novel Synchronization Invariant Audio Watermarking Scheme Based on DWT and DCT, IEEE Transactions on Signal Processing, Volume: 54 , Issue: 12, Page(s): 4835 – 484,0 2006.

[22] Petrovic, R.; Yang, D.T., Audio watermarking in compressed domain, 9th International Conference on Telecommunication in Modern Satellite, Cable, and Broadcasting Services, 2009. TELSIKS '09.

[23] Hong Zhao; Dongsheng Shen, An audio watermarking algorithm for audio authentication, IEEE International Conference on Information Theory and Information Security (ICITIS),pages: 807 – 809, Beijing, China, 2010.

[24] Al-Haj, A.; Twal, C.; Mohammad, A., Hybrid DWT-SVD audio watermarking, Fifth International Conference on Digital Information Management (ICDIM), 2010.

[25] Sharma, Shweta, JitendraRajpurohit, and Sunil Dhankar. "Survey on different level of audio watermarking techniques." *International Journal of Computer Applications* 49, no. 10 (2012): 41-48.

[26] Komal, Ms, V. Goenka, MsPallavi, and K. Patil. "Overview of Audio Watermarking Techniques.", International Journal of Emerging Technology and Advanced Engineering, Vol. 2, Issue 2, 2012.

[27] Olanrewaju, R.F.; Khalifa, O., Digital audio watermarking; techniques and applications, International Conference on Computer and Communication Engineering (ICCCE), 2012.

[28] Mahmood Movassagh, Ali AsgharBeheshtiShirazi, "A Novel Method For Real-Time Audio Watermarking Using Wavelet Transform", Canadian Conference on Electrical and Computer Engineering, CCECE 2008, pages: 83-88, Niagara Falls, ON, Canada, 2008.

Increasing the Target Prediction Accuracy of MicroRNA Based on Combination of Prediction Algorithms

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***Abstract*—MicroRNA is an oligonucleotide that plays a role in the pathogenesis of several diseases (mentioning Cancer). It is a non-coding RNA that is involved in the control of gene expression through the binding and inhibition of mRNA.**

In this study, three algorithms were implemented in WEKA software using two testing modes to analyze five datasets of miRNA families. The data mining techniques are used to compare the interactions of miRNA-mRNA that it either belongs to the same gene-family or to different families, and to establish a biological scheme that explains how the biological parameters are involved or less involved in miRNA-mRNA prediction.

The factors that were involved in the prediction process includs match, mismatch, bulge, loop, and score to represent the binding characteristics, while the position, 3'UTR length, and chromosomal location and chromosomal categorizations represent the characteristics of the target mRNA. These attributes can provide an empirical guidance for study of specific miRNA family to scan the whole human genome for novel targets. This research provides promising results that can be utilized for current and future research in this field.

Keywords—miRNA; chromosome; prediction; genome; disease; biology; DNA sequence; enzyme

I. Introduction

The cell, the basic unit of a living organism, has an extraordinary ability to reproduce, grow, respond to stimuli, and exchange a wide range of materials (metabolites) with its surrounding environment. All these tasks have been found to be heritable in nature from parent cells to progenies, and have been explained through a molecular model that has become the dogma of molecular biology.

The majority of the functions inside the cells are carried out by enzymes (Proteins and sometimes RNA). These components are orchestrated and controlled by genes. In simple terms, genes are heritable codes in the form of DNA sequence that can be transcribed into mRNA and then translated into proteins. This process is described as gene expression. Gene expression determines the fate of a cell because it controls the types of RNA and Proteins and also their exact amounts in a certain cell. Thus, all the cells in a human being contain the same DNA (genes) but due to differences in gene expression, a cell could become either a heart or a brain, or a muscle cell (with few exceptions).

Finally, Proteins is composed of amino acids, and are constructed by ribosome according to the genetic code in a process called translation. Each of the 20 amino acids is represented in the genetic code as three nitrogen bases. Proteins are the functional component of the cell; they play a role in building the structure of the cell, as enzymes (catalyzing chemical reactions), as signaling molecules (hormones), or transport vehicles, etc [1]. Messenger RNA transcript is composed of several components as discussed in [1], also miRNA can be defined as a class of short non-coding RNAs that are approximately 21 nucleotides (nt) in length [2].

A. Regulation of Gene Expression

Gene expression is regulated through a wide range of factors along with the different steps of transcription and translation. The first step of regulation occurs at the chromatin level. Chromatin is the natural packaging of DNA with special proteins that protects and controls genes inside the cell through several chemical modifications of the chromatin Histone proteins (e.g. Histone acetylating activates genes while Methylation represses them etc.) and DNA itself. DNA Methylation causes gene silencing.

Another level of control occurs at the DNA sequence level though the promoter and other upstream regulatory elements which act as a binding site ,that is (called cis-elements) for transcription factors (trans-elements) which are complexes of proteins that recruit or repress the enzymes of transcription (i.e. RNA polymerases).

After transcription, mRNA levels are controlled by its half-life through several factors. (miRNA) is believed to be a key player in the control of mRNA levels. miRNA binds to mRNA in a specific fashion and recruits a number of enzymes responsible for mRNA degradation.

Finally, which expression can be regulated at the protein level either by chemical modifications of the proteins (eg. phosphorylation) or by a feedback loop such as in the case of transcription factors that control their own genes. [1]

B. Functions of miRNA

(miRNA) plays a great role in Arranging a large number of target genes in the gene expression. Most of human miRNA genes have been defined and combined to realize a stable number of functions.

Let-7 and Lin4 miRNA are considered as some of the first discovered miRNA genes in the C.elegans worm. Talking about human and other vertebrate cell lines, tumor suppression, antiviral defense, adiposity differentiation and susceptibility to cytotoxic T-cells include some miRNA genes [2].

The MicroRNAs play important and critical roles in genetic human diseases [3, 4]. Such as, breast cancer [5] and heart diseases [6]. Nevertheless, the mechanism of gene expression that is regulated by miRNA remains ambiguous.

C. Problem Statement

Predicting miRNA-mRNA interaction by experiment is highly costly in terms of time, labor and mone. The number of miRNA and mRNA studies is increasing on a daily basis. Attempts to design biological experiments are always rendered outdated once the experiment is about to start. In addition, experiments may lack the element of discovering the novel miRNA-mRNA interactions. Thereby, data that is stacking in biological databases should be invested to discover new miRNA-mRNA interactions. The problems in miRNA-mRNA target prediction can be summarized in the following points:

- Previous studies in the field of miRNA–mRNA target prediction are scattered in different aspects of the binding process such as sequence complementarily, the binding energy (thermodynamics), etc. This limits the involvement of the factors that play a role in the prediction.
- Previous studies often use one classification method, which gives great weight to specific features on the account of others.
- miRNA are uniquely involved in complex cellular pathways that include well organized and controlled networks of genes. These networks may or may not "cross-talk" with each other. This fact was not taken into consideration in the previous studies and miRNAs were studied in bulk and not as separate families.

D. Problem Solution

Several attempts were used to apply bioinformatics techniques in order to find an optimized algorithm that can be used to explain miRNA-mRNA interaction mathematically as well as biologically. At mean time, there are several studies attempting to optimize miRNA-mRNA prediction from different aspects ranging from RNA sequence to binding energy (thermodynamics). Such algorithms can be used to screen the genome for new mRNA targets and predict miRNA-mRNA relationships that can be of a great benefit to the treatment and diagnosis of many diseases. In this study, the following solutions are taken into consideration for the prediction of miRNA-mRNA relationships:

- Factors from different aspects of miRNA-mRNA binding are given in this study, such as sequence complementarily, the binding energy (thermodynamics), etc..
- Three classification methods (i.e. decision tree, naïve bayes and support vector machine) are used.
- In order to shed the light on the uniqueness of miRNAs, five families of miRNA are studied as one collection and each one as a standalone family.

E. Knowledge discovery in Database Process

Knowledge discovery in database (i.e. KDD) is a very important process, which is the general process of converting raw data into useful information. The data mining is an integral part of this process [7].

Therefore, there are enormous and massive collection of data that is stored about the genes, proteins, and other vital information for each human being. As a result, KDD process can be applied to extract information, patterns, and new rules using different techniques [8].

F. Motivation for miRNA Research

Recently, miRNA has been found to play a key role in most cellular pathways. Thus, it is now considered one of the basic tools of gene expression regulation. miRNA has changed our textbook view of the biological process until it finally forced itself on the frontier of the biomedical sciences. One of the motivations for establishing this study is the existing of Princess Haya Biotechnology Centre (PHBC); is which a well equipped research center for biological study of miRNA where the results of this work can be experimentally validated and applied. This study can contribute to different fields of biology and medicine such as, the study of disease pathogenesis, animal models, targeted drag, drug treatment and relationship between cytogenetic (study of chromosomes) and epigenetic (study of heritable changes inflected by factors like miRNA).

G. Objectives

The main goal of this study is to use data mining for predicting the miRNA-mRNA interaction through the implementation of the following objectives:

1) Collecting the miRNA and mRNA data from databases. These data include biological parameters that are related to sequence, chromosomal location, structure folding and previous known interaction scores.

2) The use of different data mining techniques to study and compare the interaction of miRNA that is either belonging to the same gene-family or to different families.

3) Establish a biological scheme that can explain how the biological parameters are involved or less involved in miRNA-mRNA prediction.

H. Significant Contributions

This study provides an insight to the biological parameters that are involved or neglected in miRNA-mRNA target prediction, and shed some light on the mechanisms that are underlying gene silencing in cancer cellular pathways.

This study is rather significant from a clinical perspective; the establishment of a good miRNA-mRNA prediction tool can help in discovering novel gene interactions, which can open the gate for new drug targets, and novel mutated disease genes. Thus, pushing forward the process of disease treatment and diagnosis is in progress.

On the other hand, this field is still in its infancy and the nature of miRNA-mRNA interaction is still not yet understood. The establishing of new parameters that are involved in this interaction gives more light attention to the biology behind the process of gene regulation.

II. RELATED WORK

In literature, there are several researches that have been done on the miRNAs to predict their putative target mRNAs. They have been classified into different categories: researches based on computational method and probabilistic models, and researches based on machine learning methods.

A. Researches Based on Computational Method and Probabilistic Models

Hasan Ogˇul, et al. in [9] introduced a probabilistic model to show the binding preferences of miRNA and its predicted target. This model transforms an aligned duplex to represent a new sequence and used a Variable Length Markov Chain (VLMC) to determine the possibility of this sequence.

In [10], Chenghai Xue et al. Proposed a computational method to find the functional miRNA–mRNA regulatory modules (FMRMs) and to collect the miRNA in normal case and prostate cancer as a case to study the method contains groups of miRNAs and their putative target mRNAs under specific conditions. This computational method has successfully identified down-regulated patterns of mRNAs targets that are associated with prostate cancer and mRNAs associated with normal cases. Briefly, after preparing the dataset, authors applied association's algorithms in data mining to identify the biologically related miRNA–mRNA groups.

Wan Hsieh and Hsiuying Wang in [11] selected the human miRNA target prediction and suggested a generalized relative R2 method (RRSM) to discover many high-confidence prediction targets. RRSM is created based on relative rather than an absolute statistical view. In addition, it provides an efficient approach for miRNA target determination. RRSM program is available online at NCTU State website. [12]

In [13], William Ritchie et al. proposed an approach for the determination of putative miRNA targets based on a comparison between expression data of miRNAs and that of mRNAs using luciferase reporter assay. The miRNAs can decrease the expression level of targeted genes with direct correlation or indirect correlation between them. The success of this model was limited because the expression scalability of miRNA and mRNA was large. In addition, there are indirect functional relationships between two molecules.

Xiaofeng Song et al. in [14] proposed a computational method that is called microDoR to identify the mechanism of gene silencing by miRNA in humans, after they analyzed many features to find which are correlated with gene inhibition by miRNA. They found that the duplex structure of miRNA, the structural accessibility of mRNA target site region, and the numbers of binding sites are more efficient factors in identifying the target mRNA. The model that is based on SVM classifier is used to predict miRNA regulation based on these useful features. This study use all duplexes predicted by PicTar for a miRNA–mRNA interaction. The proposed approach in [14] was successful in distinguishing the mechanism by which the target mRNA is silenced either by cleavage or during translation.

In [15], Scott Younger et al. used computational methods for predicting possible miRNA targets through gene promoters and showed those promoters. Although, they are not conventionally linked to miRNA, they are strong candidates for miRNA regulation. Promoters are part of the non-transcribed sequence, and play a role in gene regulation prior to transcription. It is possible that functional correlation between promoter sequence and miRNA leads to a correlation between these sequences with their cellular pathways. Their study depends on seed sequence alignment. After that, they calculated the free energy scoring of miRNA and complementary scoring between miRNA and target sequence.

In [16], Alain Sewer et al. used a computational method to develop a program to approximate the pre-miRNA content and to predict the site of precursor miRNAs in genomic sequences. This program can be used to direct experiments to find both miRNAs that are evolutionarily conserved (i.e. miRNA has not been subjected to dramatic sequence changes because of the functional importance of the sequence) or added to species-specific miRNAs (i.e. miRNA was subjected to continuou evolutionary cycles of duplication and diversion leading to formation of sequences unique to specific species).

B. Researches Based on Machine Learning Methods

In [17], Xingqi Yan et al. used an ensemble machine learning algorithm in an attempt to improve prediction of miRNA targets. They used dataset from miRanda website [18].

This work has two major steps; in the first one, they input the biologically validated dataset, then they used feature selection (FS) to select the most informative features to be used as training data for the machine learning classifier. In addition, they used Adaptive Boosting (Adaboost) algorithm to create the ensemble classifiers that consist of several SVM classifiers to improve performance. In the second step, they used the previous one to apply this classifier on the result of miRanda. At each step, they performed evaluation processes.

In [19], Malik Yousef et al. described a target prediction method (NBmiRTar) using machine learning by a naïve Bayes classifier. The model is generated from sequence and miRNA:mRNA duplex information. Authors, used both the 'seed' and the 'out-seed' groups of the miRNA:mRNA duplex.

Their technique decreases false positive predictions and reduces the target possible number to be tested. In addition, the technique increases the sensitivity and specificity rather than the algorithms that depends on conserved genomic regions. The NBmiRTar software is available on NBmiRTar website [20]

Sung-Kyu Kim et al. created in [21] a miTarget model using a support vector machine (SVM) classifier for miRNA target gene prediction. miTarget depends on three categorized features. Those are structural, thermodynamic, and position-based features, which express the method of miRNA binding that were introduced in this study for the first time. This model produces high performance where it is compared with the previous tools. Authors are selected miR-1, miR- 124a, and miR-373 for humans using Gene Ontology (GO) analysis and discovered that significance of pairing at four, five and six positions in the 5' region of a miRNA are more essential than other seed regions.

In [22], Chenghai Xue et al. applied support vector machine to classify real versus pseudo pre-miRNAs depending on extracted features from hairpin local structure-sequence. The most important feature that defines miRNA precursors is the hairpin structures, but there are many similar hairpins that can be formed from genomic sequence. This classification helps to create a new approach to discover new miRNAs. In [33], the authors use the decision tree method to improve the accuracy of prediction. The authors discover the relationship between the data where the classified data are extracted based on rules.

It was still ambiguous when factors identify target silencing either due to transcript degradation or due to translational repression. Therefore, [23] defined two categories of target genes as the mRNA degradation (M-D) class and category the translational repression (T-R) class.

The authors of [24] noticed that the previous techniques of miRNA target prediction which were based only on sequence comparison resulted in many false positive interactions. In their work, they used the network context for filtering and support vector machine (SVM) because the topological characteristics of proteins in PPI (protein- protein interaction) networks can be used as another source of information for filtering out false positive miRNA target predictions.

III. Research Methodology

A. Overview

Most of the previous miRNA studies focused on the target prediction of miRNA binding using many features such as data mining or statistical techniques; trying to help and guide the experiments in the laboratory. Therefore, this study focuses on finding a correlation between the miRNA target sites of specific types of miRNA, namely; let-7a, let-7b, let-7c? family, mir-21 and mir-122 and the chromosomal location [i.e. q: long arm of chromosome and p : short arm of chromosome], the nucleotide sequence, binding and thermodynamic features of miRNA and mRNA. The dataset was collected from miRNA target prediction database (i.e. database using miRANDA algorithm) and then three techniques of data mining are used to investigate the miRNA-mRNA relationship by weka 3.6 software as shown in Fig.1.

All miRNA types in this study had the same length (22 nt) and were previously shown to play role in causing cancer. For instance mir-21 is involved in breast cancer pathogenesis.

In order to lower the false positives in this study, only the highest scored miRNA binding site (out of three) is included.

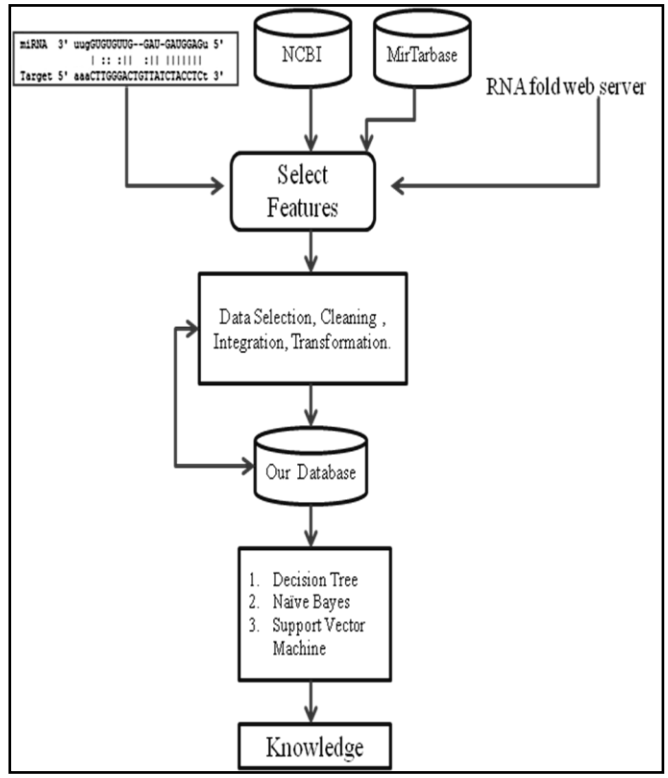

Fig. 1. The research methodology.

B. Data Set

The result of this study depends on the quality of the datasets. Therefore, the miRNA features are collected from miRTarBase database that contain more than 3500 MTIs (miRNA–target interactions). The database content is updated manually by surveying pertinent literature using filter research articles related to functional studies of miRNAs. In general, reporter assays, western blot, or microarray experiments with over expression or knockdown of miRNAs validate experimentally the gathered MITLs.

miRTarBase currently contains 4,270 experimentally verified MTIs; it contains between 669 miRNAs and 2,533 target genes amongst 14 species. The miRTarBase provides the last updated collection compared with other similar miRNA databases. In addition, it contains the largest amount of validated MTIs [25].

miRTarBase database is now available on www.miRTarBase.mbc.nctu.edu.tw

The authors of [26] updated the research article content by continuously surveying research articles. The miRTarBase database depends on miRand algorithm of target prediction and gives three positions on the 3’UTR of mRNA for the same miRNA.

In addition, the target gene information that is collected from Entrez Gene is the database that contains gene-specific at the National Center for Biotechnology Information (NCBI), it is available on www.ncbi.nlm.nih.gov [27].

The result of curation and automated integration of data from NCBI's Reference Sequence project (RefSeq) is represented by the content of Entrez Gene that collaborates model organism databases, and that takes from many other databases available from NCBI. Records that are recommended are unique, stable, and tracked integers as identifiers. The content (i.e. nomenclature, map location, gene products and their attributes, markers, phenotypes, and links to citations, sequences, variation details, maps, expression, homologs, protein domains and external databases) becomes available by updating it as new information [28].

C. Data Selection

Table 1 contains all Attributes that are included in the final dataset. Justification for the censored attributes is shown in Table 2.

TABLE I. DATASET ATTRIBUTES

NO.	Attribute	Description
1	miRTarBase ID	The ID of miRNA–target interactions in miRTarBase
2	miRNA Name	microRNA Name
3	miRNA Position	first and end sites binding
4	miRNA Length	Length of microRNA Sequence
5	Target Gene Name	The RNA Name where the miRNA bind
6	mRNA Chromosome Number	Chromosome Number that contain the Target Gene
7	mRNA Chromosome location	The Location Of Target Gene on Chromosome
8	3'UTR Length	The sequence length of three prime untranslated region.
9	miRNA target sites Position	The start and end binding position of miRNA on target gene
10	Position	miRNA binding on target gene is F or M or E
11	Score	The Score of miRNA : mRNA target gene binding
12	miRNA Sequence	A set of characters that represent a miRNA Sequence
24	Number of Mismatch	the total number of (G:U) or(G:T) binding in miRNA: mRNA duplexes
25	Number of Bulges	the total number of not binding in miRNA: mRNA duplexes
26	Number of Loop	the total number of not binding and mead loop shape in miRNA: mRNA duplexes
27	Number of Match	the total number of binding in miRNA: mRNA duplexes

TABLE II. JUSTIFICATION FOR ATTRIBUTES CENSORED FROM THE FINAL DATASET

Attributes	Justification
G% of (miRNA), C% of (miRNA), U% of (miRNA), A% of (miRNA), # G of (miRNA), #C of (miRNA), # U of (miRNA), # A of (miRNA), C+G% of (miRNA)	Low number of miRNA included in the study.
miRNA Length	All miRNA in this study were 22 nt long.
MW of (miRNA), MW of (two stranded miRNA)	Low number of miRNA included in the study.
MFE	After the experiment had no effect on the results of classification

D. Data Cleaning

In this phase, we encountered three records out of 306 records included in this study that do not have information about target gene prediction. The action was to delete them from the dataset.

E. Data Integration

Many features were collected and integrated from miRTarBase and NCBI databases, and then they are considered as attributes for this research dataset. And the RNAfold web server is used [29] to compute (Minimal Free Energy) MFE feature of target gene, as shown in Table 1.

F. Data Transformation

All features that have" indirectly" value to compute another features such as the Position attribute are selected to be added. Position attribute contains three values: First (F), Middle (M) and End (E). Thus, the position represents the relative proximity of the binding site to the end of the RNA target regardless of the 3'UTR length. Dividing the 3'UTR into three regions was important to maintain a meaningful perspective of the analysis. These values (F, M and E) are calculated by dividing the length of 3' UTR of target gene on number three. Then look up where the miRNA target sites position to determine F, M or E. for example, length of 3'UTR for BCL2 target gene is 5282 and the miRNA target sites Position is 3377-3399, so the position value will be M.

IV. DATA MINING

A. The Final Dataset

After the transformation process, each kind of miRNA was separated with these attributes to prepare the final datasets ,those attributes are: miRNA Length, Target gene Name, miRNA target sites Position, Score, 3'UTR Length , number of mismatch, number of bulges, number of loop and number of match. These attributes were selected from miRTarBase database and the last four attributes were computed manually. In addition, another two attributes were taken from NCBI database: mRNA target gene Chromosome Number and mRNA target gene Chromosome Location. A sample of the final dataset is shown in table 3.

TABLE III. SAMPLE FROM LET-7A MIRNA DATASET AFTER TRANSFORMATION STEP

3'UTR Length	mRNA Chromosome Location	Position	Score	# of Mismatch	# of Blugs	# of Loop	# of Match
492	q	F	139	3	0	3	11
5282	q	M	144	3	3	1	13
1936	q	E	132	2	1	0	8
2510	q	M	164	3	2	1	14
3893	q	M	142	3	2	1	12
3640	P	F	148	3	5	0	11
4688	P	F	134	6	1	0	10
2456	q	M	146	4	2	2	13
471	P	M	154	1	3	1	13
1399	q	M	120	3	3	2	11
2376	q	M	156	2	2	2	13
3228	q	E	137	1	2	2	13

B. Classification Techniques

This study uses the following classification technique:

- **Support Vector Machine** (**SVM**): supervised learning machine tool that is used to classify a sample of data set into two predefined classes, based on statistical analysis [30].
- **Naive Bayes Classifier**: a simple supervised learning machine tool that employs Bayes' theorem with independence assumptions among features [31].
- **Decision Tree Learning**: supervised machine learning tool that is used as a predictive model to represent all effective (i.e. higher weight) decisions. Tree Leaves represent the possible classes while the edges represent conjunctions of features [32].

Step 1: Classification Using Target Gene Chromosome Location as a Class Label.

The data mining classification algorithms are applied for each kind of miRNA where the position attribute is the class label. However, the results are reported accuracies below 50%. Therefore, we made the mRNA target gene Chromosome Location attribute to be the class label, which started to provide improvement in the accuracy. Three algorithms of classification from the weka 3.6 software are used (decision tree –J48, naïve Bayes and support vector machine -SMO) where each algorithm is applied twice on each file with different ways of data training split: Cross-validation and percentage split, in which they are the default settings.

Step 2: Classification after Addition of Chromosome Categories to the Dataset

After that, a new feature is selected to add to the features set. The mRNA target genes Chromosome Number are grouped to four categories. Therefore, four files were made for each miRNA representing one of the categories to be as a class label with the above mentioned attributes.

The four categories of chromosomes classification are the following:

1) According to gene number: where the gene number is either lower or greater than 1000.

2) According to gene size: large, medium, or short.

3) According to gene satellites: whether the chromosome contains tandem repetitive DNA satellites sequence or not.

4) According to the mix between gene size, satellites and centromeric type: "Class" .

V. EXPERIMENT AND RESULTS

In this study, three algorithms in WEKA software are used (*e.g. decision tree –J48, naïve Bayes and support vector machine -SMO*) with default setting of data training split way, Cross-validation 10 folds or percentage split 66%.

In the first step, the aforementioned three algorithms were performed on all miRNA family datasets using the position attribute as a class label. Unfortunately, the accuracy of the results is lower than 50%. However, after changing the class label to the mRNA chromosome location attribute, the result has improved. Using dataset shown in table 3, we applied classification methods using miRNA position attribute with chromosome location attribute as a class label.

The highest accuracy that is reported using decision tree algorithm in Step 1 was for miR-21 (Acc=73.68%) and let-7a (Acc= 69.23%) in 66% test mode. Whereas, in the 10 fold test mode the highest accuracy was reported in miR-21 (Acc=65.45%) and miR-122 (Acc=60.47%) as shown in figure 2A. A clear difference between 66% and 10 fold test modes was only seen in let-7a by a shift of 20%. The highest accuracy that is reported using naïve Bayes in Step 1 was seen in miR-122 (Acc=60%) and miR-21 (Acc=57.89%) in 66% test mode. Whereas, in the 10 fold test mode the highest accuracy was seen in miR-21 (Acc=67.27%) and let-7 family (Acc=57.21%) as shown in figure 2B. Using the support vector machine algorithm almost, all miRNA families provide equal accuracies that are over 50% except for let-7 family in 66% testing mode. Whereas, in 10 fold test mode all accuracy values were equal and over 50% except the let-7a as shown in Figure 2C.

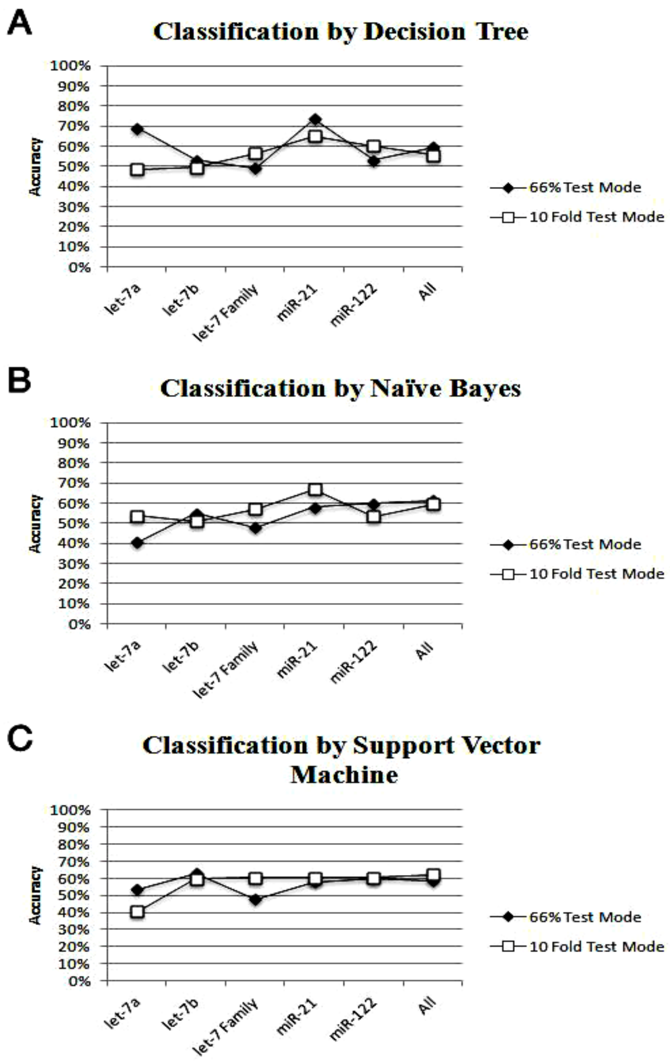

Fig. 2. The accuracy of miRNA-mRNA predictions in step 1 (before the addition of chromosome categorization) according to (A) Classification using decision tree. (B) Classification using naïve base. (C) Classification using support vector machine.

The highest accuracy that was reported using support vector machine was seen in let-7a (Acc=76.92%) and miR-21 (Acc=73.68%) in 66% test mode. Whereas, in 10 fold test mode the highest accuracy was seen in let-7a (Acc=79.49%) and miR-21 (Acc=69.09%) as shown in Figure 5C.

In general, accuracy was higher in step 2 when it is compared to step 1 using any of the three algorithms as shown in Figure 3.

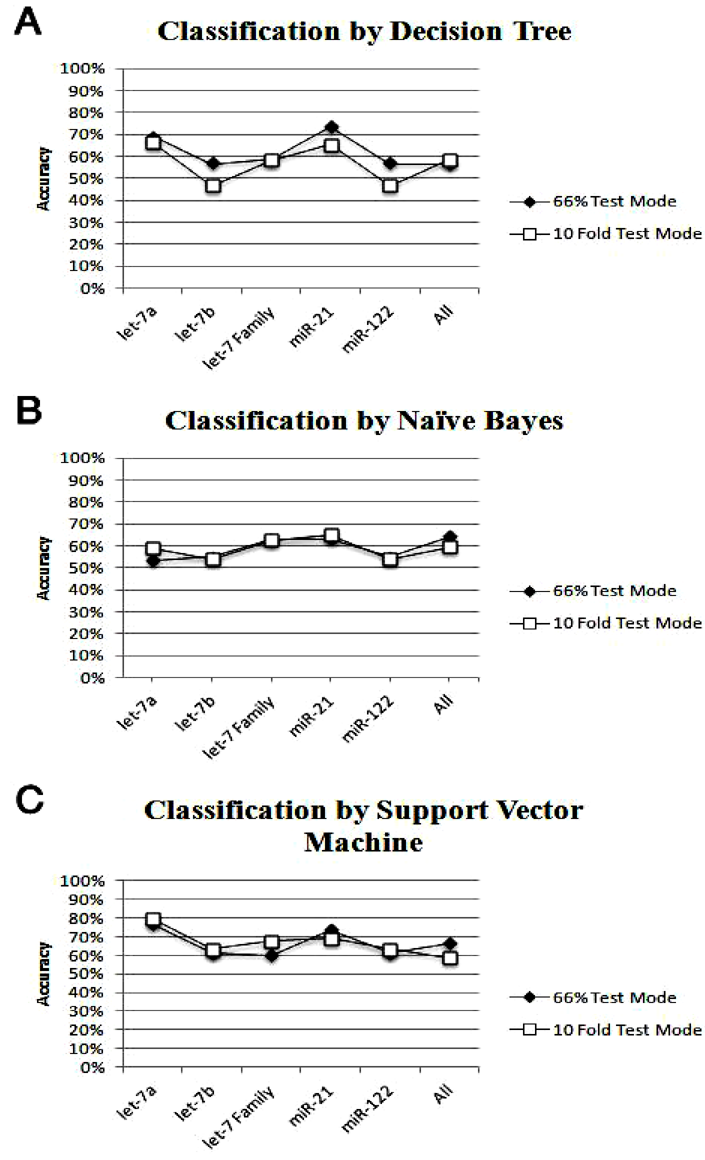

Fig. 3. The accuracy of miRNA-mRNA predictions in step 2 (after the addition of chromosome categorize) according to (A) Classification using decision tree. (B) Classification using naïve base. (C) Classification using support vector machine.

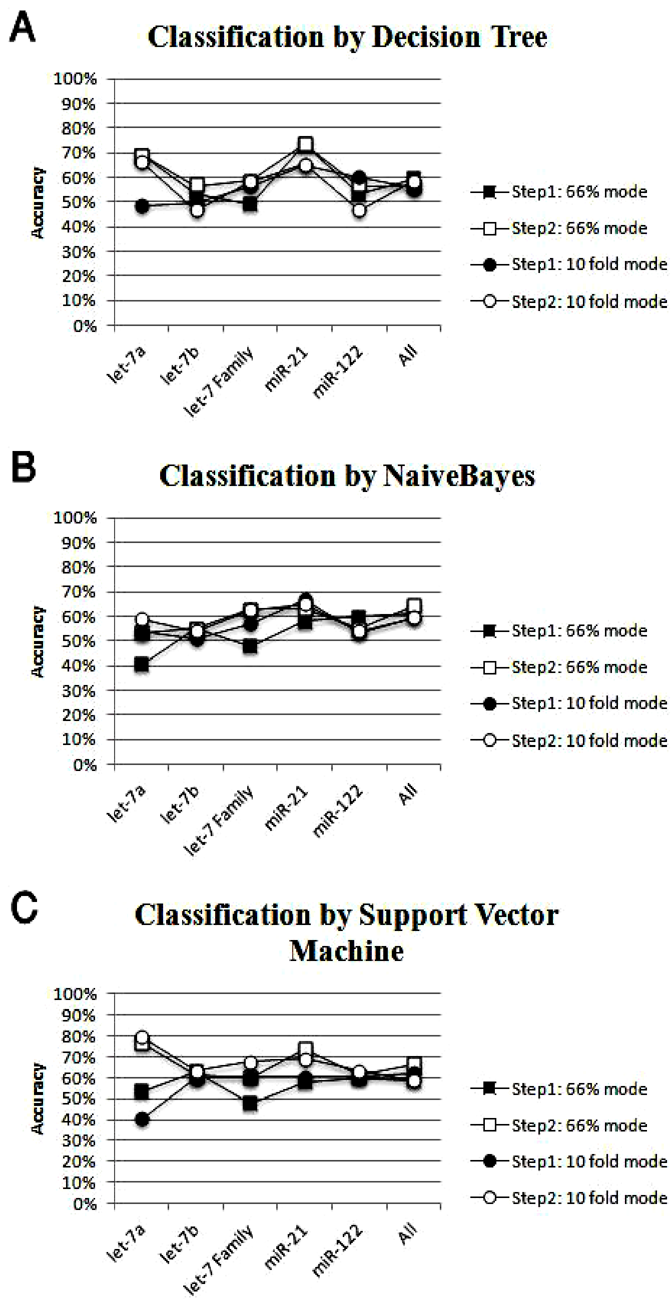

Fig. 4. The accuracy of miRNA-mRNA predictions showing differences between step 1 (before the addition of chromosome categorize) and step 2 (after the addition of chromosome categorize) according to (A) Classification using decision tree. (B) Classification using naïve base. (C) Classification using support vector machine.

In order to compare the different ways of chromosome categorization and analyze their accuracy in miRNA-mRNA prediction, four categorization methods were applied. Using the decision tree algorithm in 66% test mode, the highest accuracy in the four categorizations was reported in miR-21 (Acc= 73.68% in all categorization methods) as shown in Figure 5A. In addition, let-7a provides high accuracy in all methods (Acc=76.92%, 69.23%, 69.23%, in satellite categorization, size categorization, class categorization, respectively) except for the gene number categorization (Acc= 46.15%).

Using the naïve Bayes algorithm in 66% test mode, the accuracy in the four categorizations was reported between 46.15% to 61.54% and did not provide clear differences between miRNA families or chromosome categorizations as shown in Figure5B.Using the support vector machine algorithm in 66% test mode, the class categorization was clearly showing the highest accuracy as shown in Figure 5C.

Using the decision tree algorithm in 10 fold test mode, the highest accuracy in the four categorizations was reported in miR-21 using gene number categorization (Acc=76.36%) followed by let-7a using class categorization (Acc=66.67 %) as shown in Figure 6A.

Using the naïve Bayes algorithm in 10 fold test mode, the highest accuracy in the four categorizations was reported in miR-21 between Acc=61.82% to Acc=69.09% and all miRNA between Acc=58.82% to Acc=64.71% as shown in Figure 6B.

Using support vector machine in 10 fold test mode, the class categorization was clearly showing the highest accuracy (Figure 6C). Interestingly, let-7a showed the highest accuracy in class categorization (Acc=79.49%) and rather the lowest accuracy for the rest of categorizations (Acc=38.46% to Acc=51.28).

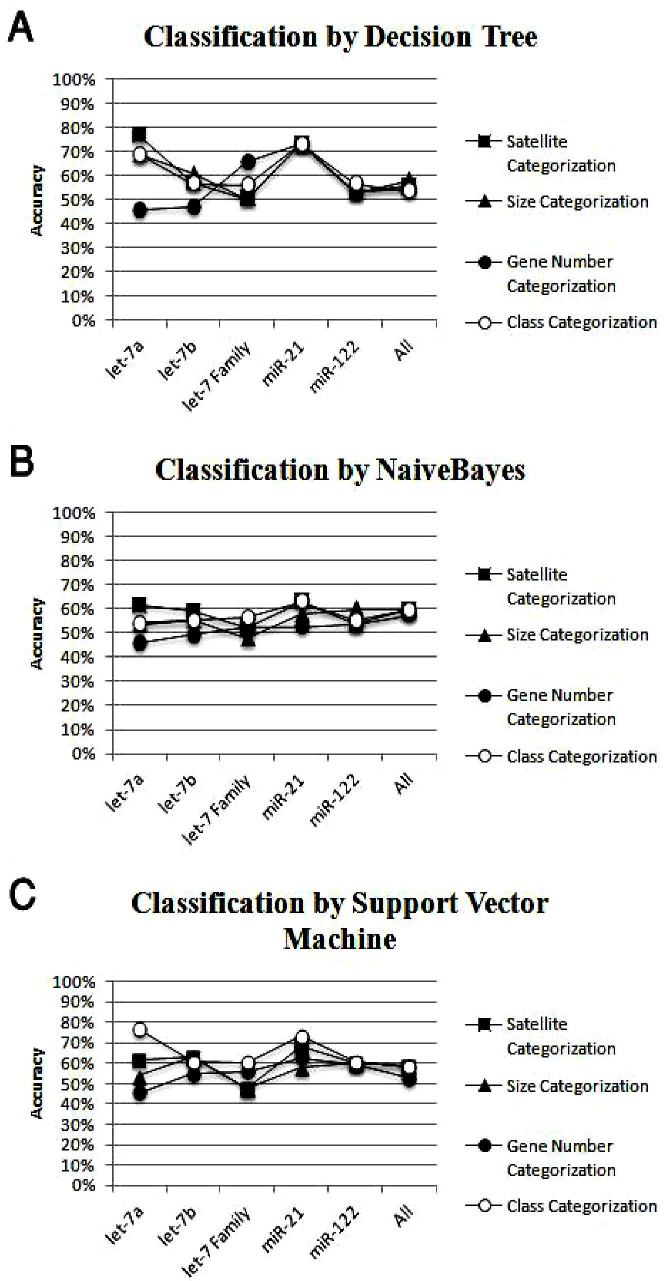

Fig. 5. The accuracy of miRNA-mRNA predictions in 66% test mode showing differences between four categorizations in step 2 according to (A) Classification using decision tree. (B) Classification using naïve base. (C) Classification using support vector machine.

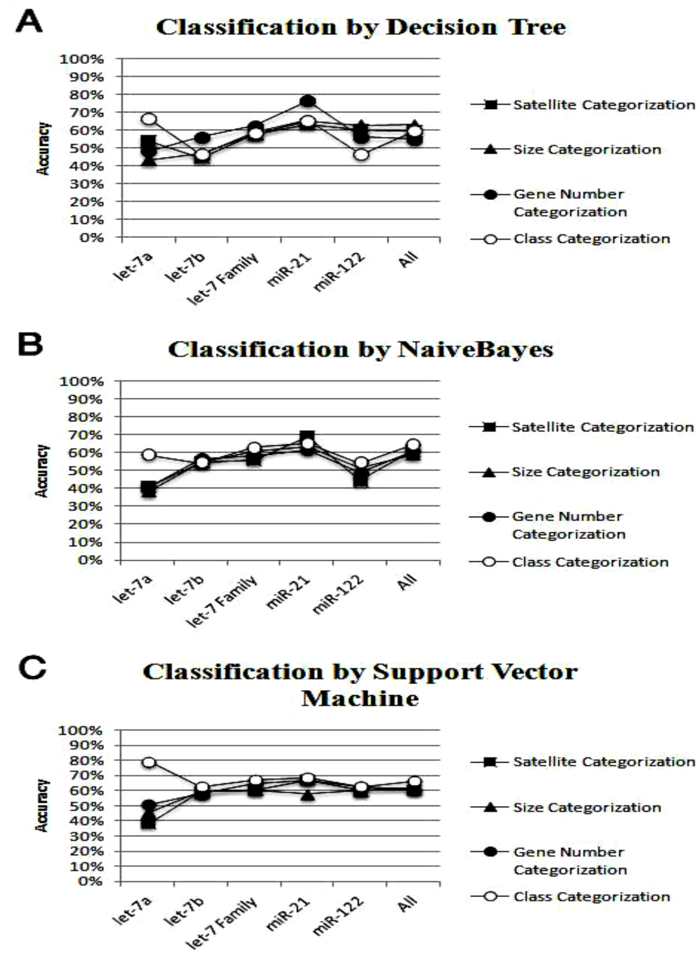

Fig. 6. The accuracy of miRNA-mRNA predictions in 10 fold test mode showing differences between four categorizations in step 2 according to (A) Classification using decision tree. (B) Classification using naïve base. (C) Classification using support vector machine.

Using chromosome class as a categorization method, the highest accuracy reported using decision tree was seen in miR-21 (Acc=73.68%) and let-7a (Acc=69.23 %) in 66% test mode. Whereas, in 10 fold test mode the highest accuracy was seen in let-7a (Acc=66.67%) and miR-21 (Acc=65.45%) as shown in Figure 2A. The highest accuracy that is reported using naïve Bayes was seen in All miRNA (Acc=64.71%) and miR-21 (Acc=63.16%) in 66% test mode. Whereas, in 10 fold test mode, the highest accuracy was seen in miR-21 (Acc=65.45%) and let-7 family (Acc=62.98%) as shown in Figure 2B.

A. *Results Discussion*

In this study, we focused on finding a correlation between the miRNA target sites of specific types of miRNA, mainly; let-7a, let-7b, let-7 family, miR-21 and miR-122 and the chromosomal location, the nucleotide sequence, binding and thermodynamic features of miRNA and mRNA. The dataset was collected from miRNA target prediction database and then three techniques of data mining (*i.e. decision tree –J48, naïve Bayes and support vector machine -SMO*) were used to investigate the correlations by weka 3.6 software with default setting of data training split way, Cross-validation 10 folds or percentage split 66%.

Data mining procedure was performed in two steps. The first step was done without adding the chromosome categorization and the second step was done with adding of any of four different chromosome categorization methods.

In general, the accuracy was higher in step 2 when it is compared with step 1 using any of the three algorithms as provided in Figure 6.

When using the decision tree in Step 1, the highest accuracy reported was for miR-21 and let-7a in 66% test mode and for miR-21 and miR-122 in the 10 fold test mode as appears in Figure 4A. In step 2, the highest accuracy reported was seen in miR-21 and let-7a in both testing modes as appears in Figure 5A. In terms of chromosome categorization, the miR-21 reported the highest accuracy in all categorization methods using the 66% test mode as appears in Figure 5A and the highest accuracy using gene number categorization in the 10 fold test mode as appears in Figure 6A. It is clear that miRNA-21 had the best accuracy, while the let-7a provided a clear decrease in the accuracy in the 10 fold test mode by 20% which might be attributed to the nature of the records that are included in the training and testing datasets. When using naïve Bayes in Step 1, the highest accuracy reported was for miR-21 and miR-122 in 66% test mode and for miR-21 and let-7a in the 10 fold test mode as appears in Figure 4B. These results were similar to the results shown in the decision tree. In step 2, the highest accuracy was seen in "All miRNA" and miR-21 in 66% test mode and in miR-21 and let-7 family in the 10 fold mode as appears in Figure 5B. Thus far, miR-21 was predominantly showing the highest accuracy in both decision tree and naïve Bayes. Additionally, let-7a provided a high accuracy level in all categorization methods (Acc=76.92%, 69.23%, 69.23%, in satellite categorization, size categorization, class categorization, respectively) except for gene number categorization (Acc=46.15 %). It is possible that the gene number categorization has this drop in accuracy due to the imbalanced number of records in let-7a (9 below 1000 genes vs. 30 over 1000 genes). In general, the 66% test mode for all categorizations reported accuracy in a low range (46.15% to 61.54%) with no clear differences between miRNA families or chromosome categorizations as appears in Figure 5B. Whereas, the 10 fold test mode for all categorizations showed the highest accuracy in the miR-21 and "All miRNA" as appears in Figure 6B. Naïve Bayes is a probabilistic statistical method that can be easily affected by the frequency of the attributes and the number of records, which again is why it was not a surprise when "All miRNA" dataset were providing a highest accuracy in many testing cases.

When using support vector machine in step 1, almost all miRNA families showed similar accuracies over 50% except for let-7 family in 66% testing mode and let-7a in 10 fold testing mode as appears in Figure 4C. In step 2, the highest accuracy reported was seen in let-7a and miR-21 in 66% test mode and let-7a and miR-21 in 10 fold test mode as appears in Figure 5C. The class categorization was clearly providing the highest accuracy in both testing modes as appears in Figure 5C and Figure 6C. Interestingly, in the 66% test mode, let-7a showed the highest accuracy in class categorization (Acc=79.49%) and rather the lowest accuracy for the rest of categorizations between (Acc=38.46% to Acc=51.28). Support vector machine is a non-probabilistic machine learning method that employs the addition of a hyperplane or more (i.e. extra dimension or dimensions). In principle, when the attributes are categorized in a larger number of groups, the algorithm gains more freedom to construct further hyperplanes (i.e. more dimensions). This can be used to explain the let-7a case where class categorization is composed of 7 groups (i.e. allowing for more dimensions). Whereas, the rest of the categorizations are composed of 2-3 groups.

Eventually, this study provides an outline of the major factors involved in miRNA-mRNA target prediction. Out of 26 features included in this study, only 9 features were retained. The rest of the features were eliminated mostly due to the low number of miRNAs included in this study except for one attribute (i.e. MFE) which had no effect ,whatsoever, on the results. MFE and the score were the only thermodynamic parameters in the study and it might be better to use more complex thermodynamic parameters in the future. The factors that were involved in prediction including match, mismatch, bulge, loop, and score represent the binding characteristics, while the position, 3'UTR length, and chromosomal location and chromosomal categorizations represent the characteristics of the target mRNA. Several attributes such as the match, mismatch, bulge, and 3'UTR length can provide empirical guidance for study of specific miRNAs using decision trees because they are classified according to an optimized cutoff value (i.e. a threshold) which cannot be inferred experimentally. In addition, some of the attributes such as the chromosomal location and chromosomal categorization have never been studied before as factors of prediction and yet they have been shown here to play a major role in the prediction. The chromosome location was a class label in this study, while the chromosomal categorizations provided the increased accuracy in prediction in all three algorithms, suggesting that they might have a major biological influence by controlling the gene expression of different cellular pathways.

VI. Conclusion and Future Work

miRNA research has been developed progressively in the past few years. Prediction of miRNA-mRNA target was attempted both computationally and experimentally. In this study, data mining techniques were used to classify a number of characteristics involved in miRNA binding and the mRNA targets themselves. Five families of miRNAs that are involved in cancer pathways have been analyzed in this study. The results can be summarized as follows:

The use of decision tree in miRNA-mRNA target prediction shows that each miRNA family behaves in a unique way when it comes to binding features with or without chromosomal categorization:

- The highest accuracy reported without chromosomal categorization was for miR-21 and let-7a in 66% test mode and for miR-21 and miR-122 in the 10 fold test mode and with chromosomal categorization the highest accuracy reported was seen in miR-21 and let-7a in both testing modes.

- The decision tree of let-7a showed the greatest weight to the mismatch followed by position and score without chromosomal categorization. While in step 2 the class categorization became the root for the tree followed by the matches and bulges.
- The decision tree of miR-21 was the same with and without chromosomal categorization. The root was the match attribute followed by 3'UTR length.
- The decision tree of miR-122 shows a clear complication and branching when the class categorization was added. The tree develops from one weight attribute in step 1 which was the 3'UTR length into a more complicated branching in step 2 including many attributes.
- Binding features such as the match, mismatch, and bulge as well as the length of the 3'UTR was shown to play major role in the classification of targets. In addition, the chromosomal source of the target that is represented here by the class categorization contributed in the accuracy of the test.

The use of naïve Bayes without chromosomal categorizations showed the highest accuracy in miR-21 and miR-122 families in 66% test mode and for miR-21 and let-7a in the 10 fold test mode. Whereas, when the chromosomal class categorization was used, the highest accuracy was seen in "All miRNA" and miR-21 in 66% test mode and in miR-21 and let-7 family in the 10 fold mode.

When using support vector machine without chromosomal categorization almost all miRNA families showed similar accuracies(over 50%) except for let-7 family in 66% testing mode and let-7a in 10 fold testing mode. When chromosomal categorization was used, the highest accuracy reported was seen in let-7a and miR-21 in 66% test mode and let-7a and miR-21 in 10 fold test mode.

Out of 26 features included in this study, only 9 features were retained. The rest of the features were eliminated either due to the low number of miRNAs included in this study or because they did not have any effect on the experimental results. The factors that were involved in prediction including match, mismatch, bulge, loop, and score represent the binding characteristics, while the position, 3'UTR length, and chromosomal location and chromosomal categorizations represent the characteristics of the target mRNA.

In the future, several attributes such as the match, mismatch, bulge, and 3'UTR length can provide a threshold-based empirical guidance for study of specific miRNAs to scan the whole human genome for novel targets.

In addition, naïve Bayes and support vector machine can be used to test the new attributes, especially the ones involved in the source of the target mRNA (i.e. chromosomal based attributes).

New findings in the field of miRNA have the potential to revolutionize the study of many diseases. Many of the known miRNA are under focus now for targeted medicine and research is now ongoing in the field of using these miRNA as drugs for treatment of different types of cancer and diagnosis.

References

[1] James Watson, Tania Baker, Stephen Bell, Alexander Gann, Michael Levine, Richard Losick. (2003) Molecular Biology of the Gene, Fifth Edition, Pearson (Benjamin Cummings) Publishing.

[2] Mohammed Abba, Heike Allgayer. MicroRNAs as regulatory molecules in cancer: a focus on models defining miRNA functions. Drug Discovery Today: Disease Models 2009; 6(1): 13-19

[3] Jürgen Wittmann, Hans-Martin Jäck. Serum microRNAs as powerful cancer biomarkers 2010; 1806: 200–207.

[4] Erik A.C. Wiemer. The role of microRNAs in cancer: No small matter. Euro pean journal of cancer 2007; 43: 1529 –1544.

[5] Cathy A. Andorfer, Brian M. Necela, E. Aubrey Thompson and Edith A. Perez. MicroRNA signatures: clinical biomarkers for the diagnosis and treatment of breast cancer. Trends in Molecular Medicine 2011; 17(6): 313-319.

[6] Haverich, Carina Gross, Stefan Engelhardt, Georg Ertl, Johann Bauersachs van Laake, Pieter A. Doevendans,el at. MicroRNAs in the Human Heart : A Clue to Fetal Gene Reprogramming in Heart Failure. American Heart Association 2007; 116: 258-267.

[7] Usama Fayyad, Gregory Piatetsky-Shapiro, and Padhraic Smyth. From Data Mining to Knowledge Discovery in Databases. AI MAGAZINE 1996; 17(3): 37-54.

[8] Pang-Ning Tan,Michael Steinbach and Vipin Kumar. Introduction to Data Mining. International Edition. Boston 2006; ISBN-10: 0321420527

[9] Hasan Ogˇul, Sinan U. Umu, Y. Yener Tuncel and Mahinur S. Akkaya. A probabilistic approach to microRNA-target binding. Biochemical and Biophysical Research Communications 2011; 413: 111-115.

[10] Bing Liu, Jiuyong Li and Anna Tsykin. Discovery of functional miRNA–mRNA regulatory modules with computational methods. Journal of Biomedical Informatics 2009; 42: 685–691.

[11] Wan Hsieh, Hsiuying Wang. Human microRNA target identification by RRSM. Journal of Theoretical Biology 2011; 286: 79–84.

[12] National Chiao-Tung University [Internet]. Taiwan: National Chiao-Tung University; Available from: http://www.stat.nctu.edu.tw/_hwang/website_wang%20new.htm

[13] William Ritchie, Megha Rajasekhar, Stephane Flamant, John Rasko. Conserved Expression Patterns Predict microRNA Targets. PLoS Computational Biology 2009; 5(9).

[14] Xiaofeng Song , LeiCheng , TaoZhou , XuejiangGuo , XiaobaiZhang , el at. Predicting miRNA-mediated gene silencing mode based on miRNA-target duplex features. Computers in Biology and Medicine 2011; 42(1): 1-7.

[15] Scott T. Younger , Alexander Pertsemlidis , David R. Corey. Predicting potential miRNA target sites within gene promoters. Bioorganic & Medicinal Chemistry Letters 2009; 19: 3791–3794.

[16] Alain Sewer, Nicodème Paul, Pablo Landgraf, Alexei Aravin, el at. Identification of clustered microRNAs using an ab initio prediction method. BMC Bioinformatics 2005, 6:267.

[17] Xingqi Yan, Tengfei Chao, Kang Tu, Yu Zhang, Lu Xie, Yanhua Gong, Jiangang Yuana, Boqin Qiang and Xiaozhong Peng. Improving the prediction of human microRNA target genes by using ensemble algorithm. FEBS Letters 2007; 581: 1587–1593.

[18] Memorial Sloan-Kettering Cancer Center. Memorial and associates; 2005 Available from: http://www.microrna.org/microrna/getMirnaForm.do

[19] Malik Yousef, Segun Jung, Andrew V. Kossenkov, Louise C. Showe and Michael K. Showe. Naıve Bayes for microRNA target predictions—machine learning for microRNA targets. Bioinformatics 2007; 23(22): 2987–2992.

[20] University of Pennsylvania education [Internet]. Philadelphia: University of Pennsylvania and associates; 2007 [updated 2012 November 1]. Available from: http://wotan.wistar.upenn.edu/NBmiRTar/

[21] Sung-Kyu Kim, Jin-Wu Nam Je-Keun Rhee, Wha-Jin Lee and Byoung-Tak Zhang. miTarget: microRNA target gene prediction using a support vector machine BMC Bioinformatics 2006; 7(411).

[22] Chenghai Xue, Fei Li, Tao He1, Guo-Ping Liu, Yanda Liand Xuegong Zhang. Classification of real and pseudo microRNA precursors using local structure-sequence features and support vector machine. BMC Bioinformatics 2005; 6

[23] Yunfei Pei, Xi Wang, Xuegong Zhang. Predicting the fate of microRNA target genes based on sequence features. Journal of Theoretical Biology 2009; 261: 17-22.

[24] M. Sualp, T. Can. Using network context as a filter for miRNA target prediction. BioSystems 2011; 105: 201-209.

[25] Sheng-Da Hsu, Feng-Mao Lin, Wei-Yun Wu, Chao Liang, Wei-Chih Huang, Wen-Ling Chan, et al. miRTarBase: a database curates experimentally validated microRNA–target interactions. Nucleic Acids Research 2011;39: 163-169

[26] National Chiao Tung University [Internet].Taiwan: National Chiao Tung University and Association; [updated 2011 October 15; cited 2011 december 25] Available from: http://miRTarBase.mbc.nctu.edu.tw/

[27] National Center for Biotechnology Information [Internet]. U.S: National Library of Medicine and Association; Available from: www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=gene

[28] Donna Maglott, Jim Ostell, Kim D. Pruitt and Tatiana Tatusova. Entrez Gene: gene-centered information at NCBI. Nucleic Acids Research 2005; 33: 54-58.

[29] University of Vienna. University of Vienna and Association; Available from: http://rna.tbi.univie.ac.at/cgi-bin/RNAfold.cgi

[30] Y.H. Qiao, J.L. Liu, C.G. Zhang, X.H. Xu and Y.J. Zeng. SVM classification of human intergenic and gene sequences. Mathematical Biosciences 2005; 195: 168-178

[31] Francesca Demichelis, Paolo Magni, Paolo Piergiorgi, Mark A Rubin and Riccardo Bellazzi. A hierarchical Naïve Bayes Model for handling sample heterogeneity in classification problems: an application to tissue microarrays. BMC Bioinformatics 2006; 7: pages numbers

[32] Shuyan Chen, Wei Wang. Decision tree learning for freeway automatic incident detection. Expert Systems with Applications 2009; 36: 4101–4105.

[33] Behzad Rabiee-Ghahfarrokhi, Fariba Rafiei, Ali Akbar Niknafs, Behzad Zamani, “Prediction of microRNA target genes using an efficient genetic algorithm-based decision tree”, FEBS Open Bio 2015; 5: 877–884

Comparative Study from Several Business Cases and Methodologies for ICT Project Evaluation

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***Abstract*—Achieving high competitive advantage through Information and Communication Technologies (ICT) has never been easy without proper management and appropriate utilization of ICT resources. Therefore, the statistics suggested that ICT project failures are very common in the organization due to several reasons; it fails to deliver the required objectives of investment, inaccurate budget planning, lack of risk management plan and time overrun are some basic reasons for an ICT project's failure. To overcome these issues, recently ICT decision makers are emphasizing more on ICT project's evaluation rather than investment. The practitioner broadly categorized the evaluation techniques in post and pre evaluation methods, which is further divided into measuring the return from financial and non-financial perspectives. The main purpose of this paper is to provide a comparative analysis on ICT investment's evaluation, their categories based on pre and post evaluation. Thus, the paper offers an extensive literature review that can help ICT decision makers and organizations to better select the evaluation techniques available, where integration of multiple techniques can further improve this process.**

***Keywords*—ICT Investment, Evaluation of ICT Investment; Multi-Dimensional Approaches; Multi-Criteria Approaches; Financial Approaches**

I. Introduction

Several studies have been conducted to discuss the issue of measuring ICT impact on organizational performance. These studies have proposed many methods, amongst which the most widely used are techniques which can evaluate the cost benefits with limited factors, or portfolio management methods which are specially constructed to provide pre-evaluation for new investments. Despite the fact that the research conducted in this study, is purely based on post-evaluation, it is additionally important to measure the non-financial values produced from particular ICT projects. Another technique to support ICT investment in an efficient way is to develop a proposal through an ICT portfolio management method. It's a pre-evaluation method, which enables analyzing several possible alternatives using graphical methods. The optimal project can be selected by visually comparing and analyzing projects [1]. The proposal-based techniques focus on business and technology domains and they make possible analysis using risk and sensitivity analysis based on previously implemented projects [2]. Yet another technique is the multi-dimensional approach which addresses assessment criteria differently from other methods, and is considered an important development in the field of measuring ICT investment [3]. The technique is basically an approach to evaluate direct and indirect benefits (business and technology) an organization can achieve post-implementation. Under this category several attempts have been made for measuring benefits where business and technology are inter-linked [4]–[8]. These techniques enable the ICT decision makers to measure the impact of ICT projects in a context-dependent manner.

To ensure successful value delivery investment, an ICT decision-maker needs to manage and focus on post implementation effects of ICT projects. Recognizing different categories of investment and associated objectives can help to evaluate it properly. However, each objective should define the key performance indicators and metrics, where the changes that occur in those metrics as determined by analysis are the real achievements after project implementation. This paper demonstrates the theoretical aspects around the ICT investment evaluation, further leading to the findings and gaps in this field. The next section highlights the current trends of ICT investment and ICT productivity paradox. After that the discussion of evaluation approaches and techniques used to measure ICT investments. This paper concludes at the barriers found in evaluating ICT investments. Finally, the paper concludes with discussion of overall findings collected through literature review. The extracted findings will lead to develop research framework and the construction of research methods for proposing framework based on the highlighted gaps found in previous studies.

A. *ICT Investment Evaluation*

The potential list of objectives from ICT investments, as discussed in the previous section, increased the organization's perception to invest more in ICT. The extensive implications of ICT inside and outside the organization make its evaluation even more complex [9]. Evaluation is important to defend the large ICT investment in realizing the real impact of ICT on business performance [10], in developing future business strategies [11], improving the decision making process [12], and finally, assessing the business values generated from ICT investments [4].

Regardless of extensive literature, proposed approaches and techniques discussed in this paper, ICT investment evaluation is a complex and debatable issue due to measuring the impact and assessing benefits, most of the time being intangible [13]. Several techniques exist, but none of them are universally adopted as every method depends on the situation, objectives and output of the particular organization [14]. Due to its disperse implications on business strategies, operational processes and cost reduction, the researcher demonstrates it as a complex task [4]. However, the evolution of assessing an ICT investment's impact on enterprises is still growing with high demands from higher management to develop and enhance the monetary aspects of their ICT resources [15]. The literature suggests that ICT is still a big pillar for supporting production and business processes which can create a large difference in economic sectors [16]. Therefore, innovative ideas are still in support to overcome the difficulties and issues in measuring the impact of ICT investments on businesses [17]–[19].

The subsequent sections comprise to answer some basic questions in order to elaborate the ICT investment such as its importance, what to evaluate from ICT investments, different kinds of approaches and techniques used in measuring ICT investments and finally, highlighted issues in measuring ICT investments.

II. Evaluation Approaches

ICT investment evaluation is a complex process for the organization to implement due to disperse impact of investment, multi-criteria decisions and the measurement process [20]. Reviewing the literature, numerous approaches proposed for evaluating ICT investments were found [4], [5], [17], [19], [21]. Researchers categorized ICT investment evaluation methodologies with different perspectives such as; financial, non-financial, multi-criteria dimensions found in literature review [3], [22]–[24]. This section discusses the wide ranges of evaluation approaches and methods developed with different characteristics as depicted in Fig. 1. Broadly, the approaches distinguished are based on the pre and post evaluation which implicitly indicates the time duration of the evaluation phase [25]. Pre-evaluation or predictive based approaches, also known as *ex-ante* or prospective approach, are for building ICT investment proposals to predict future achievable benefits and net incomes [26]. On the other side, some organizations developed the *ex-post* or retrospective approach for ICT investment's post implementation's measurement and potential ICT impacts achieved based on the organizational objectives [27]. Furthermore, approaches range from objective to subjective [28] or financial to non-financials factors [29]. Based on the literature review covered in this study, the following sub section involves discussion about evaluation approaches and techniques in detail.

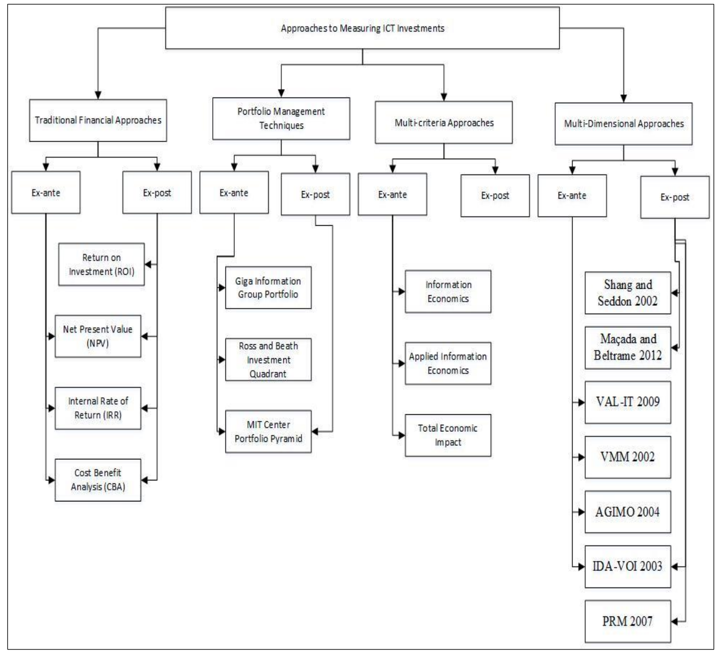

Fig. 1. Approaches to Measuring ICT Investments

A. Traditional Financial Approaches

Numerous financial approaches are developed for measuring investments in order to know the return from the investment. Individual or combinations of several financial methods have been used in researches for assessing the investment's return [30]–[33]. In this section, specially talking about financial approaches has been used in measuring investments. Return on Investment (ROI) is considered to be the most commonly used method for calculating return from investment [29]. ROI is a financial model calculate ratio between the gained profit and invested amount for a given period of time of project using the following formula:

$$ROI = \frac{(GainFromInvestment - CostOfInvestment)}{CostOfInvestment}$$

[34]

Where *CostOfInvestment* and *GainFromInvestment*, considering as total cost applied and total profit return respectively. There is a range of ROI methods, strategies, software and tools used to measure ICT investments. Using the track of ROI, several other related models have been proposed by researchers such as, Social Return on Investment (SROI) developed by Roberts Enterprise Development Fund and reworked by others [27], [35], [36] and Performance Reference Model (PRM) developed by US Federal Enterprise Architecture Program Management Office [37]. In addition, [38] proposed in his research a new ROI idea based on measuring ROI in infrastructure.

Another common method for assessing financial return based on a company's assets is called Return on Assets (ROA), a method used for finding out the utilization of company's assets in order to get the status of a company's earning profit and if it is quantifying the assets or not. In [39]

TABLE I. TAXONOMY OF TRADITIONAL FINANCIAL APPROACHES

Approach/ Sources	***What***	***How***	***Suggested Improvements***
Return on Investment (ROI) [34]	- it calculates return from an investment using financial perspective	- by calculating ratio between the profit gained and invested amount for a given period of time	- improve by including prediction capability - integration of measuring other financial & non-financial returns
Net Present Value (NPV) [40]	- it measures the difference between present value of cash inflows and outflows	- by using sum of series of in and out cash flows	- strategic aspect can improve it - integration with qualitative approach - there is room for improvement in this method
Internal Rate of Return (IRR) [41]	- it assesses and compares the profitability of investments	- by using net present value as a function of the rate of return, it calculates the attractiveness of different projects to improvise the selection process	- improvement by analytical approach - adding non-financial aspects to improve the selection process from multiple investment projects
Cost-benefit Analysis (CBA) [42]	- an analytic approach used for examining a new business investment	- the analyzed benefits of business related investments/projects summed together, and subtracted from the required cost	- addition with other non-financial approaches - inclusion of more aspects of post evaluation

definition, ROA shows a signal of how profitable a company is related to its total assets. It is calculated by using the following formula:

$$ROA = \frac{NetIncome}{TotalAssets} \quad [39]$$

Where *NetIncome* is the amount which remains after subtracting all cost of raw materials, expenditures etc., it's also known as net profit. *TotalAssets* is associated with cost of property, resources, materials, and all types of belongings while ROI calculates the return on a whole invested amount, but ROA is specially used for analyzing and measuring that. Earning profit is justifying the company's total assets. Individually, ROA doesn't provide a comprehensive measuring of the investment.

These financial methods provide an analysis very quickly by using few parameters and fixed formulas. However, applying individually can be used for different purposes such as financial return, feasibility reports, ranking between multiple projects, etc., but has been criticized due to several reasons. Using traditional financial approaches such as ROI and ROA, does not always provide a complete understanding and attainment and cannot be considered as a tool for comprehensive evaluation of ICT investments [4]. ROI only is not feasible for measuring return on investments due to its uncertainty, invisibility and difficult decision process in ICT investments [43]. [44] discussed the tangible and intangible benefits that can be achieved from ICT investment, describing that ROI provides a limited analysis for measuring return and is only used to measure hard or tangible benefits. It is now well understood that these financial approaches are not good enough to support measuring ICT investments in other non-financial perspectives such as; strategic benefits and indirect cost analysis [29], [45], [46]. Taxonomy of some common financial approaches designed by the author is presented in Table 1.

B. Portfolio Management Techniques

As discussed, the limitations in the financial approaches move the thinking of decision makers in finding alternatives for comprehensive evaluation techniques. An alternative which can deal with non-financial benefits include financial return as well. Portfolio management techniques are a kind of approach used for building pre-investment systematic project specific metrics to target the expected list of benefits to be achieved from investments as discussed in a different article found in literature review [1], [19], [24], [47] . Giga Information Group is one of the pioneers in this area developed by IT portfolio management to analyze and plan IT decisions prior to the investment [48]. It works through building proposals by analyzing the possible impact of IT on business strategies and business operations. The techniques are based on different phases during the discussion of the IT portfolio including; IT/business alignment, resource management, IT performance and reporting and etc., [48].

IT portfolio management is a kind of application used for managing and planning investments in an organized manner for all activities, processes and projects in the organization [2]. In the same way, Ross and Beath proposed IT portfolio framework, using four kinds of investment types to cover the impact of IT investment on different types of assets and services in phases [49]. It's a prospective approach that helps manage a case study by aligning IT and business strategies. The quadrants used in this approach are defined as; transformation investment, renewal investment, process improvement investment, and experiments investment. The purpose is to allocate a proper budget plan for each category while impact assessment can be more specific in this way [49].

An ICT project portfolio management technique helps in selecting the optimal project that can provide good return from the investment, but still has some limitations due to its complex selection procedure. Portfolio analysis offers an approach to prioritized multiple project investments based on different factors such as; maximization, balance, strategic alignment and resource balancing, which highlight the complexities involved in portfolio management techniques [50], selection of the project based on the feedback and historical financial data for any product. The forecast analysis for selecting a project doesn't assure the optimal return on investment. Finally, IT portfolio management is a well-known technique, but is practically not accepted and implemented in the organization on a regular basis [51]. A summary of ICT portfolio management techniques is illustrated in Table 2.

TABLE II. TAXONOMY OF IT PORTFOLIO MANAGEMENT APPROACHES

Approach/ Sources	***What***	***How***	***Suggested Improvements***
Giga Information Group Portfolio Framework [48]	- IT Portfolio management framework helps IT decision makers for new investments	- by decomposing IT portfolios into a small problems. - categorizing the business impact - classifying IT investment goals - making relationships between different scenarios	- adding other dimensions for organizational and transformational benefits into the IT project portfolio phases can be a good improvement
Ross and Beath Investment Quadrants [49]	- method for building ICT investment plans based on two axes; technology and business	- identifying list of stakeholders and funding approaches for each type of investment - measure different pools of resources	- a prospective approach which only uses four types of investment while from literature, it has been found that many other investment type exists can help it to improve further
MIT Center for Information Systems Research Portfolio Pyramid [52]	- IT investment portfolios for short and long term payoff based on four management objectives leading four IT asset classes	- by assessing four management objective returns for investing in IT; transactional, informational, strategic, infrastructure	- further improvement is possible in identifying more investment objectives to assess their impact on business processes

C. Multi-Criteria Approaches

Multi-criteria approaches are another kind of approach that can be used for assessing ICT projects pre and post evaluation purposes. Information Economics is a method which is considered a grandfather in measuring weight and rate of IT value management approaches [3]. It's highly intensive and implemented in such a complex environment such are those running in the federal government. It is used for defining business cases by providing different financial analysis such as; enhanced ROI, IRR and NPV. In addition, it also works for analyzing non-financial business impacts such as; economic impact, business domain assessment, and technology domain assessment [53].

Douglas W. Hubbard proposed an enhanced version of the multi-criteria approach as Applied Information Economics by including several other factors such as; option theory, actuarial science, measurement science, etc., [54]. It also helped measure the difference between the current state and expected value achievement. Total Economic Impact [55] is another kind of multi-criteria technique proposed by Giga.

Multi-criteria approaches provide analysis better than traditional financial approaches. A combination of financial and non-financial factors makes it a strong selection for measuring ICT investments. As shown in Table 3, most of them help in selecting optimal investments from multiple projects prospectively. Post evaluation and addition of intangible factors associated with ICT and business domain can enhance the capability of assessing the ICT investment's impact on business.

D. Multi-Dimensional Approaches

This field of study has shown remarkable improvement as many scholars have presented multi-dimension approaches, including financial and non-financial factors. Obviously, most of the investments are connected with financial values, but the ICT impact is over organizational, operational, strategic and service values are important as well as shown in Fig. 2. [1]. Several frameworks were proposed in order to cover a maximum list of values based on the organizational investment's objectives. Australian Government Information Management Office proposed a tool for measuring demand and value assessment methodologies [26]. This technique helped plan well before the investments through outlining the business case with estimated values to be achieved. Financial values, risk analysis, social and governance values are the major variables used in this method.

ICT is not just a tool for keeping and promoting organizational changes. To know its impact other than cost benefit analysis, there is a need of measurement tools for assessing productivity and customer satisfaction [56]. The IT Governance Institute (IGI) developed a framework work to ensure that IT investments fully managed and generated expected values to all stakeholders. This is an *ex-ante* approach developed to help the organization in defining IT-business cases based on value governance, portfolio management and investment management [57]. Measuring the value of ICT investments is strongly connected with different variables such as; business processes and work practices which ultimately can be assessed through productivity increase and by reducing cost [58]. In the same way, the Performance Reference Model (PRM) designed a framework to learn the performance and manage the ICT portfolio in a better way. The framework was specially built to measure the ICT investment alignment with strategic objectives [37]. The summary of multi-dimensional approaches extracted from literature review, with detailed descriptions for each one provided in Table 4.

TABLE II. TAXONOMY OF MULTI-CRITERIA APPROACHES

Approach/ Sources	*What*	*How*	*Suggested Improvements*
Information Economics (IE) [53]	- a method for measuring and justifying the value and impact of IT investments based on business performance	- define the business case - cost benefits analysis - enhanced ROI, IRR and NPV - measuring values linking - value acceleration - value restructuring and innovation	- improve by post evaluation process to provide the analysis for the decision makers in future investments - there is space to improve this method by evaluating other intangible values
Applied Information Economics [54]	- multi-criteria decision analysis approach in order to optimize decisions in the ICT investment environment	- define the business case - model the current state - compute the value - measure the high value - optimize decision	- enhance the model by adding intangible benefits measurement process, which can incorporate the analysis with strategic objectives of the enterprise
Total Economic Impact, Giga Research, [55]	- a pre-evaluation technique through which an organization assesses projects and take decisions incorporated with business goals	- prepare a business case and assess the bases of the following components: * Impact on IT or project cost * Impact on the business or business benefits * Future options created or future flexibility * Risk or uncertainty	- good method for selecting a project based on criteria mentioned in the methodology, but there is a possibility to increase its efficiency by assessing intangible factors associated with the investment

Multi dimension approaches are considered better evaluation approaches as compared to traditional financial approaches [4]. The point is to correctly identify the impact of ICT based on the organizational objectives for which investment is allocated. This study also focused on multi dimension approaches for measuring the ICT investment based on the investment's objectives linked with direct and indirect benefits and finally, to assess the business values associated with ICT investments. Discussion for each of the selected researching we are emphasizing in this research is discussed in section 2.4, related work.

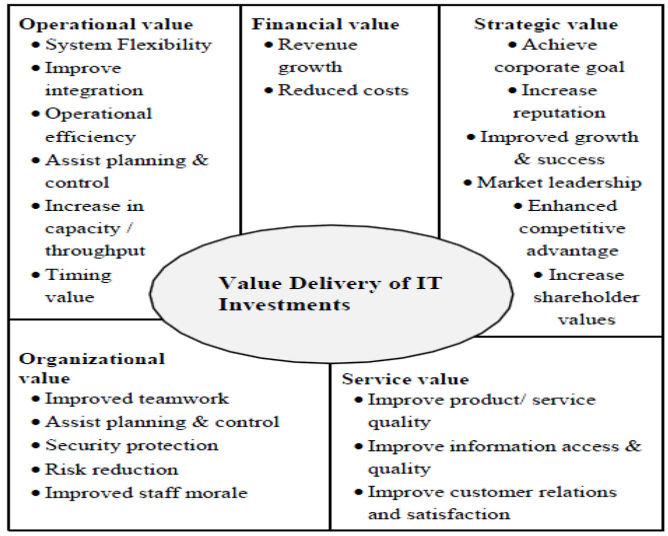

Fig. 2. Model for Value Delivery of ICT Investment [1]

TABLE III. TAXONOMY FOR MULTI-DIMENSIONAL APPROACHES

Approach/ Sources	*What*	*How*	*Suggested Improvements*
IT Business Value Model – Brazil [4]	- IT business value model for the assessment of benefits generated from IT investments - implemented proposed model and refined the model by excluding one dimension	- using surveys, by combinations of models extracted from literature review - implemented integrated framework based on 5 dimensions - instrument treated by statistical techniques	- framework can improve by applying other sectors - more dimensions can be added for assessment such as; managerial and operational - implementation of the framework on a large population can create more solid results
VMM [59]	- It works on three basic elements; cost, value and risk. - It delivers the structure, tools and techniques for complete quantitative analysis and association of values.	- develop a decision framework - alternative analysis - pull together the information - communicate and document	- more comprehensive approach towards measuring value or generated benefits after investment - post measurement framework - create a model which can emphasize more on value rather than cost
IDA-VOI, European Commission, DG [60]	- A project of European Commission Directorates General Enterprises to assess the public complex environment of IT and interchange data between administrations (IDA).	- process analysis - benefits identification - valuation of benefits - valuation of costs - net benefits	- emphasizes more on how non-financial factors can improve the model -implementation of the model in other environments can improvise the credibility of measuring values
PRM, FEAPMO,	- framework for measuring the	- cause and effect	- organizational and informational

USA [37]	performance of Federal/Government agencies at a strategic level	relationship between inputs, outputs and outcomes - structured around measurement areas, measurement categories, measurement grouping and measurement indicators	impact over strategic objectives can be a good addition - more emphasis on post non-financial perspective can improve this model
Assessing and Managing the Benefits of Enterprise System (ES) - Australia [6]	- Measures benefits of ES using online published web cases implemented by three vendors - Benefits generated years after implementation, using five dimensions and 25 sub-dimensions	- by integrating models published in previous studies Four Steps Process: - Search and review vendor websites - Identify benefits using literature review - Implement proposed framework on selected web cases - Consolidated list of benefits	- Interview instruments with experts for framework validity - implementing proposed framework in growing organization to assess live data - ICT investments as a whole can create different results and values - adding or deleting dimensions is possible based on several reasons

III. Issues in ICT Investment Evaluation

During the last two decades, several discussions and developments have been presented by various scholars and practitioners in regards to ICT investment evaluation. Some evaluation models have been developed for a specific organization's structure [27], [57], [59], [61], [62] while others have only considered limited factors for the evaluation process [34], [40] which is not suitable for the comprehensive evaluation process of ICT investment. As discussed earlier, ICT investments involve different objectives and reasons, such as mandatory IT, strategic IT, transformational IT, and new infrastructures [63], [64]. [65] described several reasons for ICT project failure, including the lack of proper evaluation techniques being applied to measure ICT investments. Therefore, there is still a need for general purpose, comprehensive and easy-to implement evaluation models and methodologies based on financial and non-financial impact factors which need to be evaluated concurrently.

Moreover, the ICT investment evaluation performs in several transitions, such as on the IT transformation phase [66] and IT implementation and development phases [67]. Based on the review of previous literatures and research, the overall process of ICT investment evaluation is not an easy task due to its scattered impact and implementation for different resources. As discussed by [29], an organization measuring return on ICT investments is complex and requires a thorough understanding and knowledge of both (i) processes involved in the business and (ii) the environment in which they are running. Therefore, it is essential to know the relationships among the risks, benefits, and costs of ICT investments as well as multidimensional environmental factors, including societal, organizational, and institutional issues [29].

ICT evaluation involves several stages and branches to be evaluated simultaneously during the allocated evaluation period. In growing organizations, investments in ICT comprise of application software, system software, programming languages, communication, hardware [68] equipment, services, and other technologies [69]. Although the technological aspect in the evaluation process is the major phase, this cannot ignore the management, services and product aspects of the investment. It is easier to calculate and measure investments using variables like cost and expected financial return, but risks, benefits, and services create many hurdles in the evaluation [70]. Although it is significant to quantify IT asset's value, especially in IT service-related contexts [38] to improve customer satisfaction, the measurement of ICT investments is still progressing by building and developing models and methodologies to support organizational decisions. The following issues are involved in measuring ICT investments, as illustrated by [71]:

- In IT investments, there are lots of benefits of an intangible nature.
- IT investments sometimes lead to long-term benefits.
- Sometimes benefits of IT investment are indirect; these can be evaluated by using several complex matrixes and factors.
- The theories and techniques available are somewhat unsuitable for understanding and capturing the business value of IT.

The literature review supports that the complete process of evaluation of ICT investments is still under progress which requires a thorough understanding of multi-dimensional factors where the business value and cost return may exist. [29] suggests that if any organization calculating returns on investment from ICT investments may be considered a complex process and needs thorough understanding and knowledge of all kind of processes involved in the business and environment where they are running. There are different kinds of models developed together with multiple aspects, but decision makers are still looking for completed and reliable methods to assess their decisions. [20] stated that to assist the ICT decision makers, there are no dependable, reliable, and optimal techniques, which can evaluate their decisions as well as investments.

IV. Conclusion

This paper highlighted the importance of ICT projects in an organization to better run their business process, to get competitive advantage and reasons for using technology oriented business model for more benefits. However, the literature review suggests that ICT project can fail due to several reasons. Therefore, using of proper pre-evaluation techniques help decision makers to plan well, and post evaluation may provide the analysis on utilization of ICT resources.

ICT projects evaluation is a complex and multi-dimensional process needs extra efforts, integration of different dimensions and techniques based on organizational requirements. The research findings suggest that ICT investment is not self-governing projects, all of the investments are to support business process and structure of the organization to run in more efficient way. Combination of business and technology is the real motto of current organizational scenario. The better way of measurement can lead the organization towards best utilization of ICT resources. The list of measuring techniques showed that it is a multipart procedure divided into pre and post evaluation which is further divided into several others methods. The number of researches presented in this paper increased the importance of this research area, where practitioners and academicians both are still progressing for standard method or tool to evaluate the ICT project. In future, evaluation of ICT projects using real case studies through different kinds of measuring techniques discussed in this paper can improve the idea of ICT investment evaluation.

References

[1] F. Ahmad and N. H. Arshad, “Value Delivery of Information Technology Investment: A Conceptual Framework,” Int. J. Comput. Theory Eng., vol. 6, no. 2, p. 150, 2014.

[2] S. Bonham, IT Project Portfolio Management. ARTECH HOUSE, INC. 685 Canton Street Norwood, MA 02062, 2005.

[3] M. McShea, “IT Value Management Creating a Balanced Program,” IEEE IT Pro, no. November, pp. 31–37, Dec-2006.

[4] A. C. G. Maçada and M. M. Beltrame, “IT business value model for information intensive organizations,” BAR-Brazilian …, pp. 44–65, 2012.

[5] S. Gregor, M. Martin, W. Fernandez, S. Stern, and M. Vitale, “The transformational dimension in the realization of business value from information technology,” J. Strateg. Inf. Syst., vol. 15, no. 3, pp. 249–270, 2006.

[6] S. Shang and P. B. Seddon, “Assessing and managing the benefits of enterprise systems: the business manager’s perspective,” Inf. Syst. J., vol. 2000, pp. 271–299, 2002.

[7] J. Turner and H. Lucas, Developing Strategic Infomation Systems, Guth W. Boston, MA: Handbook of Business Strategy, Warren, Gorham and Lamont, 1985.

[8] P. Weill and M. Broadbent, Leveraging the new infrastructure: how market leaders capitalize on information technology. Harvard Business Press, 1998.

[9] P. Powell, “Evaluation of information technology investments: business as usual,” Beyond IT Product. Parad., 1999.

[10] Y. A. A. Arabyat, “The Dynamics of Information Technology Investment and the Financial Performance of the Banking Sector in Jordan,” University of Western Sydney, 2012.

[11] P. G. W. Keen, Shaping the Future: Business Design Through Information Technology. University of California: Harvard Business School Press, 1991.

[12] H. Lucas, Information technology: Strategic decision making for managers. John Wiley & Sons, 2008.

[13] R. Gomez and S. Pather, “Ict Evaluation : Are We Asking the Right Questions?,” Electron. J. Inf. Syst. Dev. Ctries., vol. 50, no. 5, pp. 1–14, 2012.

[14] J. Ward, “Keynote Speech,” in 10th European Conference on Information Technology Evaluation, 2003.

[15] D. Remenyi, A. Money, and F. Bannister, The effective measurement and management of ICT costs and benefits. Elsevier, 2007.

[16] B. Nault and D. Mittal, “Investments in Information Technology: Indirect Effects and Information Technology Intensity,” Inf. Syst. Res., vol. 20, no. 1, pp. 140–154, 2009.

[17] N. M. Ongaki and F. W. Musa, “A Framework for Evaluating Ict Use in Teacher Education in Kenya,” Int. J. Res., vol. 2, no. 4, pp. 65–95, 2015.

[18] J. Manuel and C. Pérez, “Assessing the impact of Information and Communication Technologies on the Portuguese hotel sector : an exploratory analysis with Data Envelopment Analysis,” Tour. Manag. Stud., vol. 11, no. 1, pp. 35–43, 2015.

[19] R. Sabherwal and A. Jeyaraj, “Information Technology Impacts on Firm Performance: An Extension of Kohli and Devaraj (2003),” MIS Q., vol. 39, no. 4, 2015.

[20] M. J. Schniederjans, J. L. Hamaker, and A. M. Schniederjans, Information Technology Investment Decision-Making Methodology, Illustrate. World Scientific Publishing Co., 2010.

[21] P. Weill, “The relationship between investment in information technology and firm performance: A study of the valve manufacturing sector,” Inf. Syst. Res., vol. 3, no. 4, pp. 307–333, 1992.

[22] B. Ranti, “A Review of Information Technology Investment Evaluation Methodologies: The Need for Appropriate Evaluation Methods,” Pros. Konf. Nas. Teknol. Inf. Komun. untuk Indones., no. 4, pp. 112–115, 2006.

[23] E. Khakasa, “Evaluating Information Technology Investments - A Survey of Kenyan Commercial Banks,” Proc. 10th Annu. Conf. IAABD, no. 1992, pp. 473–480, 2009.

[24] W. Van Grembergen and S. De Haes, “Measuring and demonstrating the value of IT,” IL 60008 USA, 2005.

[25] A. M. Cresswell, G. B. Burke, and T. Pardo, Advancing return on investment, analysis for government IT: a public value framework. Center for Technology in Government, University at Albany, SUNY, 2006.

[26] AGIMO, “Demand and Value Assessment Methodology,” Canberra, Australia, 2004.

[27] S. Olsen, J. Nicholls, B. Biemann, S. Bonini, J. Emerson, S. Robertson, P. Scholten, and R. Tolmach, “SROI Framework: A Framework for Approaches to SROI Analysis,” USA, 2005.

[28] M. Wilson and D. Howcroft, “Power, politics and persuasion in IS evaluation: a focus on ‘relevant social groups,’” J. Strateg. Inf. Syst., vol. 14, no. 1, pp. 17–43, 2005.

[29] L. Dadayan, “Measuring return on government IT investments,” in Proceedings of the 13th European Conference on Information Technology Evaluation, 2006, no. September, p. 12.

[30] M. Nijland, “IT cost benefit management improvement from a critical perspective,” in Proceedings of the Eighth European Conference on Information Technology Evaluation, 2001.

[31] B. De Jong, P. Ribbers, and H. van der Zee, “Option pricing for IT valuation: A dead end,” Electron. J. Inf. Syst., vol. 2, no. 1, 1999.

[32] C. Toffolon and S. Dakhli, “Software Informative Prototyping Evaluation”,” Electron. J. Inf. Syst. Eval., vol. 5, no. 2, 2001.

[33] A. Fairchild, “Enabling usage-based IT costing in the banking sector,” Electron. J. Inf. Syst. Eval., vol. 6, no. 2, pp. 87–94, 2003.

[34] ROI, “Return On Investment (ROI) - Investopedia,” 2016. [Online]. Available: http://www.investopedia.com/terms/r/returnoninvestment.asp. [Accessed: 02-Nov-2015].

[35] E. Jed, J. Wachowicz, and S. Chun, “Social Return on Investment:Exploring Aspects of Value Creation in the Nonprofit Sector,” 2000.

[36] K. Harji, “Social Return on Investment,” 2008.

[37] PRM, “The Performance Reference Model,” Washington D.C, 2007.

[38] M. McShea, “Return on infrastructure, the new ROI,” IT Prof., vol. 11, no. 4, pp. 12–16, 2009.

[39] ROA, “Return on Assets,” 2016. [Online]. Available: http://financial-dictionary.thefreedictionary.com/return+on+assets. [Accessed: 03-Nov-2015].

[40] NPV, “Net Present Value Definition,” 2016. [Online]. Available: http://www.investopedia.com/terms/n/npv.asp. [Accessed: 03-Nov-2015].

[41] IRR, “Internal Rate of Return -Investopedia,” 2016. [Online]. Available: http://www.investopedia.com/exam-guide/series-65/quantitative-

methods/rates-of-return-internal-rate-of-return.asp. [Accessed: 02-Mar-2016].

[42] CBA, “Cost-Benefit Analysis (CBA) - Investopedia,” 2016. [Online]. Available: http://www.investopedia.com/video/play/costbenefit-analysis-cba/.

[43] M. Benaroch and R. Kauffman, “Justifying electronic banking network expansion using real options analysis,” MIS Q., vol. 24, no. 2, pp. 197–225, 2000.

[44] N. Donald, “Value on Investment in Higher Education,” Educ. Cent. Appl. Res. Bull., vol. 2003, no. 18, 2003.

[45] J. Ballantine and S. Stray, “Information systems and other capital investments: evaluation practices compared,” Logist. Inf. Manag., vol. 12, no. 1/2, pp. 78–93, 1999.

[46] P. Gustafsson, J. Huldt, and H. Lofgren, “Improving the value assessment of IT investments: A case study,” PICMET ’09 - 2009 Portl. Int. Conf. Manag. Eng. Technol., pp. 3167–3175, 2009.

[47] Z. Irani and P. E. D. Love, “The propagation of technology management taxonomies for evaluating investments in information systems,” J. Manag. Inf. Syst., vol. 17, no. 3, pp. 161–177, 2001.

[48] C. Gliedman, “The Many Faces of IT Portfolio Management,” Res. Dig., vol. 5, no. 3, pp. 1–10, 2002.

[49] J. Ross and C. Beath, “Beyond the Business Case: Strategic IT Investment,” p. 14, 2001.

[50] R. Cooper, S. Edgett, and E. Kleinschmidt, “Portfolio management in new product development: Lessons from the leaders--I,” Res. Technol. Manag., vol. 40, no. 5, p. 16, 1997.

[51] B. Maizlish and R. Handler, IT (information technology) portfolio management step-by-step: Unlocking the business value of technology. John Wiley & Sons, 2010.

[52] G. Westerman, “IT Risk Management : From IT Necessity to Strategic Business Value,” Massachusetts Inst. Technol., p. 15, 2006.

[53] M. Parker and R. Benson, “Information Economics,” Inf. Econ., no. C, pp. 1–15, 1989.

[54] D. Hubbard, How to measure anything: Finding the value of intangibles in business, Reprint. John Wiley & Sons, 2014.

[55] C. Gliedman, “The Foundation of Sound Technology Investment : The Total Economic Impact TM Methodology,” 2003.

[56] J. Dedrick, V. Gurbaxani, and K. Kraemer, “Information technology and economic performance: A critical review of the empirical evidence,” ACM Comput. Surv., vol. 35, no. 1, pp. 1–28, 2003.

[57] VAL-IT, “ENTERPRISEVALUE: GOVERNANCE OF IT INVESTMENTS,” IL 60008 USA, 2009.

[58] E. Brynjolfsson and L. Hitt, “Beyond Computation: Information Organizational Transforimation and Business Perforimance,” J. Econ. Perspect., vol. 14, no. 4, pp. 23 – 48, 2000.

[59] VMM, “The Value Measuring Methodology,” 2002.

[60] IDA-VOI, “IDA Value Of Investment,” 2003.

[61] SROI, “Analyzing the Value of Social Purpose Enterprise Within a Social Return on Investment Framework,” California, San Francisco, 2001.

[62] PSV, “Public Service Value,” Accenture, 2006.

[63] I. van der Zee and T. Han, Measuring the value of information technology. IGI Global, 2002.

[64] H. Lucas, Information technology and the productivity paradox: Assessing the value of investing in IT, Illustrate. Oxford University Press, 1999.

[65] H. Nawi, A. A. Rahman, and O. Ibrahim, “Government’s ICT project failure factors: A revisit,” in International Conference on Research and Innovation in Information Systems, 2011, pp. 1–6.

[66] P. Kraynak, “Finding Your True IT Transformation,” IT Prof., vol. 11, no. 6, pp. 37–41, 2009.

[67] R. Taylor and B. Zhang, “Measuring the Impact of ICT: Theories of Information and Development,” in Telecommunication Policy Research Conference, 2007, pp. 1–39.

[68] P. Weill and M. Olson, “Managing Investment in Information Technology: Mini Case Examples and Implications,” MIS Q., vol. 13, no. 1, pp. 3–17, 1989.

[69] P. W. Keen, Every manager’s guide to information technology: a glossary of key terms and concepts for today's business leader, Revised. Harvard Business School Press, 1995.

[70] E. Brynjolfsson, “Technology’s true payoff,” Inf. week 496, vol. 34, no. 6, 1994.

[71] G. Giaglis, N. Mylonopoulos, and N. Mylonopoulos, “The ISSUE methodology for quantifying benefits from information systems,” Logist. Inf. Manag., vol. 12, no. 1/2, pp. 50–62, 1999.

A Novel Algorithm for Optimizing Multiple Services Resource Allocation

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***Abstract*—Resource provisioning becomes more and more challenging problem in cloud computing environment since cloud-based services become more numerous and dynamic. The problem of scheduling multiple tasks for multiple users on a given number of resources is considered NP-Complete problem, and therefore, several heuristic based research methods were proposed, yet, there are still many improvements can be done, since the problem has several optimization parameters. In addition, most proposed solutions are built on top of several assumptions and simplifications by applying computational methods such as game theory, fuzzy logic, or evolutionary computing. This paper presents an algorithm to address the problem of resource allocation across a cloud-based network, where several resources are available, and the cost of computational service depends on the amount of computation. The algorithm is applicable without restrictions on cost vector or compaction time matrix as opposed to methods in the literature. In addition, the execution of the algorithm shows better utility compared to methods applied on similar problems.**

Keywords*—Cloud computing; Cloud Services; Scheduling; Parallel and Distributed systems

I. Introduction

Cloud computing [1] has emerged recently as a new paradigm that moved enterprise computing from the classical host-based architecture pattern into the elastic computing pattern. This new service-oriented vision delivers resources and applications on-demand based on the pay-per-use concept. The cloud system should provide the application users with robustness, fault tolerance, execution automation, and powerful computing facilities. This implies various cloud service requirements and QoS to be maintained. Therefore, several challenges arise throughout the design development and deployment of these systems. In addition, unlike conventional software and hardware systems, a wide range of different issues should be considered in the design and operation of cloud based systems. On the other hand, the size of data centers have been continuously increased in order to accommodate the increasing demand while at the same time reducing the management costs. Finally, virtualization has been heavily used in order to increase the utilization of server resources by consolidating many virtual machines into a single physical server. Therefore, as cloud-based services become more numerous and dynamic, resource provisioning becomes more and more challenging.

While QoS problems in service and cloud based systems have been addressed in the literature, the problem of constrained resource allocation problem attracts a lot of attention, as it is considered difficult problem since it is affected by several aspects, such as assumptions about the services, tasks, subtasks, and communication between servers. The problem of scheduling multiple tasks for multiple users on given number of resources is considered difficult, and therefore, several research methods were proposed, yet, there are still many improvements can be done, since the problem has several optimization parameters and in addition, most proposed solutions are built on top of several assumptions and simplifications.

In this paper, we address the problem of resource allocation in which service demanders intend to solve sophisticated parallel computing problem by requesting the usage of resources across a cloud-based network, where several resources are available, and the cost of computational service depends on the amount of computation. The contributions in this paper include providing a simple algorithm for resource allocation for single user with multiple subtasks. Then, propose another algorithm for the multiple users problem using a selection function. The proposed algorithm is illustrated on example that was proposed in the literature, and the proposed method in this paper outperforms previous ones by two aspects: first, it can be applied on the general case without any restriction on the type of the computation time matrix for resource, nor on the cost function, as opposed to previous work. Second, the algorithm provides better schedule in terms of utility.

The rest of this paper is organized as follows: Section II provides a brief review on the state of the art on the subject. Section III describes the formalization of the single and multiple users problem. Section IV presents the proposed algorithm to solve the single user scheduling problem. Section V presents a selection function based algorithm for scheduling the multiple users problem. The proposed method is illustrated on an example in Section VI. Finally Section VII concludes the paper with future work hints.

II. Related Work

In this section we present a brief state of the art review on related work that addressed the problem of resource allocation in cloud computing. In fact, more detailed reviews can be found in several surveys, for instance, [2], [3], [4], [5], [6], and [7].

Walker *et al.* [8] presented a model in which the resultant profit is calculated by obtaining the storage space from cloud. Buyya et al. [9] have proposed an infrastructure for resource allocation in multiple clouds based on commodity pricing method. The work in [10] used virtualization in order to allocate data center resources dynamically based on application demands and support. The authors used skewness to measure the unevenness in the multidimensional resource utilization of a server and combined different types of workloads hoping to improve the overall utilization of server resources by reducing skewness. The work in [11] proposed a resource allocation technique by ranking the tasks of users based on error criteria to maintain the consistency in the priorities of the tasks. The authors in [12] presented a web semantic based resource allocation method using multi-agent technologies to model interoperability between the users and different resource.

Ergu *et al.* [13] proposed a model for task-oriented resource allocation in a cloud computing environment based on available resources and user preferences. The method considers response time as the measure in their allocation procedure. Genetic algorithms based tasks scheduling in cloud systems were addressed in [14], [15], and [16]. The work in [17] addressed distributed convergence to fair allocations of CPU resources for time-sensitive applications for applications with service-level adaptation, that are executed by each application independently. The work in [18] addressed resource allocation in computational mobile grid.

Karthik *et al.* [19] suggested to allocate the resources based on the speed and cost of different VMs in IaaS. It differs from other related works, by allowing the user to select VMs and reduces cost for the user. Zhen Kong *et al.* [20] proposed a mechanism to allocate virtualized resources among selfish VMs in a non-cooperative cloud environment. Hence, VMs care essentially about their own benefits without any consideration for others. Paul *et al.* [21] allocated cloud resources by obtaining resources from remote nodes when there is a change in user demand¿ In this method over-provisioning and under-provisioning of resources can cause several issues. The work in [22] dynamically allocated CPU resources to meet QoS objectives by first allocating requests to high priority applications. This method depends on prioritizing tasks which has several limitations in cloud environment. The work in [23] proposed to use live migration as a resource provisioning mechanism but all of them use policy based heuristic algorithm to live migrate VM which is difficult in the presence of conflicting goals.

Several other computing techniques were adopted for resource allocation in cloud computing. For instance, game theory has also been used in several locations for resource allocation in cloud computing, for instance in [24], and [25]. Several other methods used fuzzy pattern recognition to propose dynamic resource-allocation algorithms for multiple cloud nodes such as [26], [27], and [28]. On the other hand, cloud resource allocation using auction mechanism is addressed in [29], [30], [31], [32], and, [33]. These mechanisms does not ensure profit maximization due to its truth telling property under constraints.

Despite the large amount of work on the subject, there is still lack of practicable solution for cloud computing systems because most cloud-based computational services are multiple QoS-constrained, in order to improve the utility of scheduling algorithms [25]. The problem addressed in this paper considers multi-users with dependent tasks, each is composed of several subtasks to be scheduled on multiple resources. This paper presents a generic solution that can be applied the problem without the constrains on the execution time and cost imposed in previous work. The proposed mechanism is based on utility function trying to find a local optimum solution for the NP-hard problem.

III. Problem Description and Formalization

We first present problem description for resource allocation for a single user, then we describe the general case, for multiple users as presented in previous work. A user u has a service S that is composed of k sub tasks that are parallel and dependent subtasks with equal amount of computation. In fact, this assumption is practical, since in case of unequal amounts of computing, the cost values of resources can be adjusted to normalize the amount of commutations for tasks. There are m computational resources that are available to the user, $\{R_1, R_2, ..., R_m\}$. Each resource, R_j, has a fixed price p_j according to its capacity forming the price vector $p = \{p_1, p_2, ..., p_m\}$. In addition, each resource R_i require specific time, t_i, to execute any subtask forming the execution time vector $t = \{t_1, t_2, ..., t_m\}$. The objective is to assign subtasks for each user to a number of resources such that the the total cost is minimized, where cost represents the expense and execution time for completing tasks for all users. The scheduling problem solution is a non-negative vector v of m elements, each represent the number of subtasks assigned for each resource. The entry v_i is the number of subtasks of the task S allocated to resource R_i. The allocation vector v must satisfy $\sum_{i=1}^{m} v_i = k$.

We derive two vectors from vectors v, t, and p as follows: the first is the completion time vector, $\hat{t}$ and the second is the expense vector $\hat{e}$. The entry $\hat{t}_i$ of $\hat{t}$ is the turnaround time it takes for resource R_i to complete v_j subtasks of the task S. The entry $\hat{e}_i$ of vector $\hat{e}$ is the expense S pays for resource R_j to complete v_j subtasks. These two vectors are defined as follows: $\hat{t} = v \cdot t$, $\hat{e} = v \cdot t \cdot p$. Based on these we calculate two values for schedule v, the total execution time t_{max}, and the total expense e_v. The execution time for task S is the maximum execution time of tasks assigned to resources, $t_{max} = max\{\hat{t}_i | \hat{t}_i \in \hat{t}\}$, where $\hat{t}_i$ denotes the i^{th} element of the vector $\hat{t}$. The total expense e_v is the summation of all expenses paid to all resources, $e_v = \sum_{i=1}^{m} e_i$. We assign weights for schedule costs as follows, w_t for execution time weight, and w_e for expense weight. Then we can define a merit value of the expense using the following utility function: $u(v) = \frac{1}{w_t \times t_v + w_e \times e_v} = \frac{1}{w_t \times max\{\hat{t}_i | \hat{t}_i \in \hat{t}\} + w_e \times \sum_{i=1}^{m} e_i}$ The objective is to find v that maximizes u. while we will present our proposed methodology for a generalizers case, as opposed to the presented solution in there. Next we give an example to illustrate the problem described above. Given five computational resources $(R_1 - R5)$, $m = 5$, and given the price vector $p = (1, 1.2, 1.5, 1.8, 2)$, there is a task (S), that has three subtasks, $k = 3$. The execution time vector for each subtask using above resources is given as $t = (5, 4.2, 3.6, 3, 2.8)$. Assume that a schedule $v = (1, 1, 1, 0, 0)$ is used, then we can calculate $\hat{t}$ and $\hat{e}$ as follows: $\hat{t} = (5, 4.2, 3.6, 0, 0)$ and $\hat{e} = (5, 5.04, 5.4, 0, 0)$, then we can calculate, $t_v = 5$ and $e_v = 15.44$. Assuming $w_e = w_t = 1$, then $u = \frac{1}{t_v + e_v} = 0.0489$. On the other hand, the schedule $v = (0, 0, 1, 1, 1)$ will yield to $u = 0.05$.

Next, we present the model for the problem with multiple users sharing the same number of resources as described above. Given n users $\{u_1, u_2, ..., u_n\}$, who are interested in executing n services, $\{S_1, S_2, ..., S_n\}$, where every S_i is one single task that is composed of k_i subtasks, that are parallel and dependent subtasks with equal amount of computation. $k = \{k_1, k_2, ..., k_n\}$ represents the number of subtasks for all users. There are m computational resources that are shared by all users, $\{R_1, R_2, ..., R_m\}$ with price vector p. All users who allocate their services to resource R_j proportionally share the capacity and expense of resource R_j. In addition, each resource R_i require specific time, t_{ij}, to execute subtask τ for user u_j using resource R_i, forming the execution time vector T_i for every resource. The collection of all vectors $T_1, T_2, \ldots, T_m$ forms the execution time matrix T. Since all subtasks of S_i are parallel and dependent, the completion time of task S_i is defined similar to above as $max\{T_{ij} | T_{ij} \in T_i\}$, where T_{ij} denotes the element of matrix T in row i and column j.

The objective is to assign subtasks for each user to a number of resources such that the the total cost is minimized, where cost represents the expense and execution time for completing tasks for all users. The scheduling problem solution is a non-negative matrix A of m rows and n columns, each element represents the number of subtasks assigned for each resource. The entry A_{ij} is the number of subtasks of the task S_i allocated to resource R_j. The allocation matrix A must satisfy the following constraint $\sum_{j=1}^{n} A_{ij} = k_j$, where $j = \{1, 2, \ldots, m\}$.

We derive two matrices from matrix T, schedule A, and vector p as follows: the first, is the completion time matrix, $\hat{T}$ and the second is the expense matrix $\hat{E}$. The entry $\hat{T}_{ij}$ of $\hat{T}$ is the turnaround time it takes for resource R_j to complete A_{ij} subtasks of the task S_i. The entry $\hat{E}_{ij}$ of matrix $\hat{E}$ is the expense user S_i pays for resource R_j to complete A_{ij} subtasks. These two matrices are defined as follows:

$$\hat{T}_{ij} = \sum_{l=1}^{n} A_{lj} \cdot T_{lj},$$

$$\hat{E}_{ij} = \frac{\hat{T}_{ij} \cdot p_j}{\sum_{l=1}^{n} A_{lj}}.$$

Based on these two matrices, we calculate two vectors for schedule A, the first vector, T_{max}, is composed of m elements, each element T_{max_i} represents the execution time for task S_i using schedule A, and is defined as the maximum execution time of tasks assigned by user i to all resources, $T_{max_i} = max\{\hat{T}_{ij} | j = \{1, 2, ..., n\}\}$. The second vector, E_{sum}, is composed of m elements, each element, E_{sum_i}, represents the total expense for user S_i, and is defined as the summation of all expenses paid to all resources by user i, $E_i^A = \sum_{j=1}^{m} \hat{E}_{ij}$. We assign weights for schedule costs as follows, w_t for execution time weight, and w_e for expense weight. Then we can use definition for a merit value of the expense use the utility function defined above: $u_i^A = \frac{1}{w_t \times T_i^A + w_e \times E_i^A} = \frac{1}{w_t \times max\{\hat{T}_{ij} | j=\{1,2,...,n\}\} + w_e \times \sum_{j=1}^{m} \hat{E}_{ij}}$. Then the utility of schedule A can be defined as the summation of utilities of all users: $u^A = \sum_{i=1}^{n} u_i^A$.

Next we give an example to illustrate the problem described above for multiple users. We will use a similar problem to the one described in [25], however, problem description in [25] is based on the following two assumptions: (1) the price vector of all resources $p = (p_1, p_2, .., p_m)$ satisfies $p_1 < p_2 < \cdots < p_m$, and (2) the corresponding execution time of any subtask of an arbitrary task S_i satisfies $T_{i1} > T_{i2} > \cdots > T_{im}$. We believe that the above assumption is valid for only limited applications, and the method used based on game theory can have a Nash equilibrium only under the given assumption. The algorithm proposed in this paper can be applied on any price vector, p, and execution time matrix, T, regardless of the order. We will explain the problem statement using the same example, since it is going to be used as illustrative example on the proposed algorithm later. Given the price vector p described above, $k = \{2, 3, 4\}$, the execution time matrix T and schedule A given as below, then we calculate the two matrices $\hat{T}$, $\hat{E}$ and two vectors T_{max} and E_{sum} as follows:

$$T = \begin{pmatrix} 6 & 5 & 4 & 3.5 & 3 \\ 5 & 4.2 & 3.6 & 3 & 2.8 \\ 4 & 3.5 & 3.2 & 2.8 & 2.4 \end{pmatrix}, \quad A = \begin{pmatrix} 0 & 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 0 & 1 \end{pmatrix}$$

$$\hat{T} = \begin{pmatrix} 0 & 0 & 0 & 7 & 6 \\ 0 & 8.4 & 7.2 & 6 & 0 \\ 4 & 7 & 6.4 & 0 & 4.8 \end{pmatrix}, \quad \hat{E} = \begin{pmatrix} 0 & 0 & 0 & 6.3 & 6 \\ 0 & 5.04 & 5.4 & 5.4 & 0 \\ 4 & 4.2 & 4.8 & 0 & 4.8 \end{pmatrix}$$

$T^A = (7,\ 8.4,\ 7)$, $E^A = (12.3,\ 15.84,\ 17.8)$

$$u_i^A = \begin{pmatrix} \frac{1}{7+12.3} = 0.0518135 \\ \frac{1}{8.4+15.84} = 0.0412541 \\ \frac{1}{7+17.8} = 0.0403226 \end{pmatrix}, \text{ and finally}$$

$u^A = \sum_{i=1}^{n} u_i^A = 0.13339.$

This example shows the optimization needed in order to enhance utility of the scheduling problem, while there is tradeoff between the execution time and the price for every assignment. First, a proposed solution for the single user case is provided, where the optimum solution can be obtain. In fact, while similar problems have been addressed in the literature, we believe that the solution we provide is the most efficient one. The algorithm for the multiuser problem, which is considered NP compete problem, will be based on a selection function that is designed using the solution for the single user problem. We define a function that calculates the effect of scheduling tasks into resources, and use it for the choice of proper allocation of every service.

Algorithm 1 Singel User Resource Allocation

procedure SINGLE USER ALLOCATION
  Input: k, m, t, p, n.
  Output: v.
  Initialize:
  • Initialize vectors and variables
   $v = 0$, $\hat{t}_{max} = 0$, $j = 0$; initialize all elements to 0

  • Initialize the allocation function vector δ
  REPEAT
    $\delta_j = p_j \times t_j + t_j$
    $j = j + 1$
  UNTIL $j = k$; simulation time ends
  • Process all elements elements using allocation function
   $j = 0$; Reset counter
  REPEAT
    find l such that
     (1) $1 \leq l \leq n$,
     (2) $\forall i \cdot 1 \leq i \leq n \Rightarrow \delta_l \leq \delta_i$,
    $v_l = v_l + 1$, allocate current task to R_l
    if $v_l \times t_l > t_{max}$ ***then***
     $t_{max} = v_l \times t_l$
    endif
    $\delta_l = max(t_{max}, t_l \times (1 + v_l)) + p_l \times t_l \times (1 + v_l)$,
    $j = j + 1$
  UNTIL $j = k$; all tasks are allocated
  END
end procedure

IV. OPTIMIZING SINGLE USER SCHEDULING

In this section we present the solution for the single user optimization problem based on the description in the previous section. The objective is to find the allocation vector v the maximizes the utility $u(v)$. For k subtasks and m resources, it is obvious that the search space for the problem is non-polynomial, hence exploring all possible scenarios is nonlinear.

In order to show how the proposed algorithm finds the optimum solution, we first create a variable t_{max} and initiate it to 0. Then, we define a selection function, δ, as a vector of m elements, $\delta = (\delta_1, \delta_2, \ldots, \delta_m)$, which is defined initially as follows:

$$\delta_i = max(t_{max}, t_i \times (1 + v_i)) + p_i \times t_i \times (1 + v_i).$$

Then, we start the allocation of k subtasks by following an iterative process, where in every iteration, we assign one subtask into one resource. We choose l, such that satisfies the following conditions: (1) $1 \leq l \leq n$, and (1) $\forall i \cdot 1 \leq i \leq n \Rightarrow \delta_l \leq \delta_i$. This means that δ_l is minimum in δ. Then, we assign the current subtask into resource R_m. After the assignment, we modify the schedule v by incrementing v_l, calculate the new $\hat{t}_l$, δ_l, and $\hat{t}_{max}$. Then we repeat the process again, until all items are processed.

This algorithm has a complexity of worst case $O(nm)$, i.e. it should perform in linear time vs $n \times m$. Applying the above algorithm on the single user example explained above will result in $v = (0, 0, 1, 1, 1)$, with utility $u = 0.05$. In addition considering the scheduling problem for multiusers presented in the previous section, if the problem is solved individually, i.e. every user schedule his subtasks using the algorithm 1 above, then, the resulting schedule will be $v_1 = (0, 0, 0, 1, 1)$, $v_2 = (0, 0, 1, 1, 1)$, $v_3 = (1, 1, 1, 0, 1)$, all combined together will give schedule A provided below. Hence, under this assumption, the schedule for multiuser will have the utility of $u^A = 0.1273$. Obviously, this is not the optimum solution for the multiuser case. For instance, the schedule given in the example in the previous section yields better utility. Therefore, in the next section, we parent a selection function based algorithm for utility optimization for the multiuser scheduling problem described above.

$$A = \begin{pmatrix} 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 \\ 1 & 1 & 1 & 0 & 1 \end{pmatrix}$$

V. OPTIMIZING MULTI-USER SCHEDULING

The algorithm is developed based on the fact that the single user algorithm alone does not lead into the optimum solution when generalized into the multiple users case. Obviously the reason, is that any subtask scheduled at a given resource, affects the execution time of that resource for other users. Therefore, we will develop the scheduling algorithm based on two issues: scheduling subtasks as pairs, and using a selection function that takes into account the current optimum choice for the single users scheduling problem and combine it with other facts, such as the number of unscheduled subtasks. In fact, The objective is to find the allocation matrix A the maximizes the utility u^A form a given execution time matrix T and price vector p. The problem is described in the literature as NP-Complete, and hence heuristic based solutions can be used to provide the best possible solution. For n users, each has k_i subtasks, where $1 \leq i \leq n$, and m resources, we first create two empty matrices $\hat{T}$ and $\hat{E}$, each of $n \times m$ elements and initialize them to zeros. We also create the two vectors T_{max}, and E_{sum}, each of n elements, and a variable T_E, all initialized to zeros as well. Let Δ be a matrix of $n \times m$ elements, initialized as follows: $\Delta_{ij} = p_j \times T_{ij} + T_{ij}$.

Next, we define a vectors, T_A of m elements initialized to zero, represents the total number of subtasks assigned to every resource. At any time during the scheduling process, $T_{A_j} = \sum_{i=1}^{m} A_{ij}$ and, $T_E = \sum_{j=1}^{m} E_{sum_j}$. Finally, we define the selection function, $\Theta_i = 0.01 \times k_i + \frac{1}{\Delta_{il}}$, that takes into account the number of unscheduled subtasks, where Δ_{il} is minimum in row i in the matrix Δ.

Subtasks are then allocated for users using the selection function, Θ, to choose two users, α and β, such that $1 \leq \alpha, \beta \leq n$, and the following two conditions are satisfied, (1) $\forall i \cdot i > 0, i \leq n \Rightarrow \Theta_\alpha \geq \Theta_i$, and (2) $\forall i \cdot i > 0, i \leq n, i \neq \alpha, \Rightarrow \Theta_\beta \geq \Theta_i$. Then, for each user, α and β , we choose the entry that leads to best single user utility using the single user optimization algorithm, γ_α for task α, and γ_β for task β, such that $1 \leq \gamma_\alpha \leq k_\alpha$, and $1 \leq \gamma_\beta \leq k_\beta$, and the following two conditions are satisfied: (1) $\forall j \cdot j > 0, j \leq m \Rightarrow \Delta_{\alpha\gamma_\alpha} \leq \Delta_{\alpha j}$ and (2) $\forall j \cdot m > 0, j \leq n, j \neq \gamma_\alpha \Rightarrow \Delta_{\beta\gamma_\beta} \leq \Delta_{\beta j}$. Hence, two subtasks with minimum values in Δ are to be scheduled for two user .

In fact, the assignment of the two subtasks are chosen simultaneously for a valid reason, when a single subtask is assigned the allocation matrix will be modified, and hence the local utility matrix Δ will be modified. After several considerations, it was found that sleeting a single subtask and assigning it to the best available entry Δ_{ij} leads to bad

Algorithm 2 Multiple User Resource Allocation Algorithm

procedure ALLOCATION
  Input: k, n, m, T, p.
  Output: A.
  Initialize:
  • Initialize vectors and variables
  $A = \{0\}$, $T_{max} = \{0\}$ $E_{sum} = \{0\}$, $T_E = 0$, $\hat{T} = \{0\}$; initialize all elements to 0

  • Initialize the allocation function vector Δ
   $i = 0$
  REPEAT
   $j = 0, i = i + 1$
   REPEAT
    $\Delta_{ij} = p_j \times T_{ij} + T_{ij}$
    $j = j + 1$
   UNTIL $j = m$;
  UNTIL $i = n$;
  • choose two elements using selection function
  REPEAT
   • choose α and β using selection function Θ.
   • choose γ_α such that $\Delta_{\alpha\gamma_\alpha}$ is minimum
   • choose γ_β such that $\Delta_{\beta\gamma_\beta}$ is minimum and $\gamma_\beta \neq \gamma_\alpha$
   • Schedule subtask for user α at Resource R_{γ_α}
   • Schedule subtask for user β at Resource R_{γ_β}
   • updates all variables for by assigning subtask for user α assigned to service γ_α
    $A_{\alpha\gamma_\alpha} += 1$, $T_{A_{\gamma_\alpha}} += 1$,
    $\hat{T}_{\alpha j} = \hat{T}_{\alpha j} + p_i \times T_{ij}$,
    $T_{max_\alpha} = max(T_{max_\alpha}, \hat{T}_{\alpha j})$
    $E_{sum_\alpha} = E_{sum_\alpha} + p_\alpha \times T_{\alpha j}$
    $T_E = T_E + p_\alpha \times T_{\alpha j}$
    $\Delta_{ij} = p_i \times T_{ij} + \sum_{l=1}^{n} max((T_{A_l} + 1) \times T_{il}), T_{max_l}) + T_E.$
    $k_\alpha = k_\alpha - 1.$
   • updates all variables for by assigning subtask for user β to resource γ
   • Repeat above steps using β and γ_β instead of α and γ_α, respectively.
  UNTIL at most one task has unscheduled subtasks
   • choose α such that $k_\alpha > 0$
  REPEAT
   • choose γ_α such that $\Delta_{\alpha\gamma}$ is minimum.
   • updates all variables for α and γ
   $k_\alpha = k_\alpha - 1.$
  UNTIL $k_\alpha = 0$
  END
end procedure

schedule, due to the effect of every single subtask scheduled on the final commutation time (maximum time) for every user. We then update the list of parameters in two steps, each for one assignment. All variables $\hat{T}$, Δ, T_{max} , E_{sum},T_A, and T_E are updated as follows for each task assignment of subtask for user α by scheduling at at service γ_α as follows:

$$A_{\alpha\gamma_\alpha} += 1,\ T_{A_{\gamma_\alpha}} += 1\ ,\ \hat{T}_{\alpha\gamma_\alpha} = \hat{T}_{\alpha\gamma_\alpha} + p_{\gamma_\alpha} \times T_{\alpha\gamma_\alpha},$$

$$T_{max_\alpha} = max(T_{max_\alpha}, \hat{T}_{\alpha\gamma_\alpha}),$$

$$E_{sum_\alpha} = E_{sum_\alpha} + p_\alpha \times T_{\alpha\gamma_\alpha},$$

$$T_E = T_E + p_\alpha \times T_{\alpha\gamma_\alpha},$$

$$\Delta_{ij} = p_i \times T_{ij} + \sum_{l=1}^{n} max((T_{A_l} + 1) \times T_{il}), T_{max_l}) + T_E.$$

Values in the matrix Δ are updated based on the best utility for the single user case described in the previous section. In the next step of the same iteration, the same process is repeated for the assignment of the subtask of user β for service γ_β. In the next iteration, the function Θ is used to select two tasks, and the function Δ is used to select two schedules for each tasks, and then, the best combination is selected. The process is repeated until all tasks are scheduled. In case, there is only one task left with one or more subtasks, then direct assignment using the function Δ is conducted until all subtasks are processed. The outcome depends on the selection function, i.e., the order on which the users are selected for scheduling and the resource their subtasks are allocated to. Hence, we intend to test the algorithm for more than one selection function. Algorithm 2 shows the step by step description of the process and is illustrated on a detailed example in the next Section. In addition, the algorithm is tested with tow different selection functions, and in both it outperforms evolutionary and game theory based algorithms.

VI. Illustrative Example

Let us consider the multi-user example given in Section 3, and demonstrate the algorithm above in order to find an appropriate allocation matrix. All initial values for inputs are as given in the example above. We start calculating initial values using the algorithm above, then we choose $\alpha = 3, \beta = 2$ using the selection function. Then we choose two entries in Δ with minimum values: $\gamma_\alpha = 5$ and $\gamma_\beta = 4$. The combination $(\gamma_\alpha, \gamma_\beta) = (5, 4)$ is selected, hence, a subtask for user u_3 will be scheduled to service R_5, followed by a subtask of user u_2 to service R_4. Based on this, the allocation matrix, A, will be updated with these schedules in the next step. This is illustrated in the initial step indicated as λ_0 in Table I below, where the numbers in bold represent the active ones.

In the next step, λ_1, k_3 and k_2 are decremented, leading to $k = \{2, 2, 3\}$. All variables are updated and new selection function values are calculated, which will lead to $\alpha = 3, \beta = 2$, $\gamma_\alpha = 2$, $\gamma_\beta = 3$. Hence, subtask for user u_3 is assigned to R_2, and for user u_2 is assigned to R_3, which will appear in A in the next step λ_2, where k becomes $\{2, 1, 2\}$, and the selection functions gives $\alpha = 3, \beta = 1$, $\gamma_\alpha = 1$, and $\gamma_\beta = 5$. Hence, subtask of u_3 is assigned to R_1, and subtask of u_1 is assigned to R_5. The step λ_3 leads to $k = \{1, 1, 1\}$, $\alpha = 3, \beta = 2$, $\gamma_\alpha = 2$, and $\gamma_\beta = 4$. Hence, subtask of u_3 is assigned to R_2, and subtask of u_2 is assigned to R_4. In step λ_4, $k = \{1, 0, 0\}$, therefore only user u_1 has subtasks, selection function for $\alpha = 1$ will give $\gamma_\alpha = 3$, hence, the last subtask for user u_1 is assigned to R_3. The final allocation matrix obtained as below, which give $u^A = 0.134$. Note that this utility value is better than the result obtained using game theory with Nash equilibrium in [25].

$$A = \begin{pmatrix} 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 2 & 0 \\ 1 & 2 & 0 & 0 & 1 \end{pmatrix}$$

We observed that the selection function has direct effect on the outcome for the algorithm, therefore, we did execute the algorithm by choosing the selection function as follows $\Theta_i = \frac{1}{1+k_i} + \frac{1}{\Delta_{il}}$, then applying the above steps will lead into the schedule A given below, which has a utility of $u^A = 0.1416$, obviously, this shows an enhancement of around 6.2% over the utility in achieved in [25].

$$A = \begin{pmatrix} 0 & 0 & 0 & 0 & 2 \\ 0 & 0 & 1 & 2 & 0 \\ 2 & 2 & 0 & 0 & 0 \end{pmatrix}$$

TABLE I: Execution of the algorithm on the above example

Step	A	Δ	k	Θ	α, γ_α	β, γ_β
	0 0 0 0 0	12.0 11.0 10.0 9.8 9.0	2	0.131		
λ_0	0 0 0 0 0	10.0 9.2 9.0 **8.4** 8.4	3	**0.149**	3, **5**	2, **4**
	0 0 0 0 0	8.0 7.7 8.0 7.8 **7.2**	4	**0.179**		
	0 0 0 0 0	27.6 26.6 25.6 31.9 30.0	2	0.059		
λ_1	0 0 0 1 0	22.6 21.8 **21.6** 24.0 26.2	2	**0.066**	3, **2**	2, **3**
	0 0 0 0 1	21.2 **20.9** 21.2 26.8 22.8	3	**0.078**		
	0 0 0 0 0	38.9 46.4 44.5 42.6 **40.2**	2	**0.046**		
λ_2	0 0 1 1 0	33.3 40.2 35.9 34.7 35.8	1	0.040	3, **1**	1, **5**
	0 1 0 0 1	**31.4** 34.6 38.2 36.4 33.0	2	**0.052**		
	0 0 0 0 1	59.4 56.4 55.8 53.9 55.6	1	0.028		
λ_3	0 0 1 1 0	58.8 56.2 **53.2** 52.0 60.0	1	**0.029**	3, **2**	2, **4**
	1 1 0 0 1	51.4 **50.6** 54.2 52.4 54.4	1	**0.030**		
	0 0 0 0 1	71.4 76.9 **67.6** 72.2 67.6	1	0.025	1	
λ_5	0 0 1 2 0	68.4 73.5 65.0 66.8 69.6	0	0.015	3	
	1 2 0 0 1	63.4 66.1 64.4 67.8 66.4	0	0.016		
	0 0 1 0 1		0			
λ_6	0 0 1 2 0		0			
	1 2 0 0 1		0			

VII. Conclusion and Future Work

While cloud computing technology is increasingly being used, effective resource allocation methods are required in order to maximize profit for cloud service providers, provide energy efficient methods, and at the same time achieving user satisfaction. This paper proposes a model for task-oriented resource allocation in cloud computing, where the problem of scheduling single user with multiple dependant subtask on multiple available resources with different execution time and cost is addressed first. Then, the general problem of scheduling multiple users, each with multiple subtask on multiple available resources is addressed. The proposed solution is provided by introducing a selection pairwise function based on subtasks completion time and task costs. The problem addressed in this paper is described as NP-Complete, hence, the presented solution present a local optimum schedule. The proposed method, compared to existing techniques, is applicable on scheduling problems without any restrictions on the execution time and price, in particular as compared to game theoretic approaches [25], where the execution time must be given in ascending order, and the price in descending in order to find Nash equilibrium. In addition, the proposed method outputs schedule with better utility than game theoretic one.

We intend to provide implementation for the method, and test for problems with large number of users and resources. In addition, we intend to try to modify the selection function to further improve the utility of the schedule by considering the weight of the subtasks to be scheduled in the future including price and completion time. In addition, since formal methods have been proposed thouroughly for the analysis of differnt cloud applications [34], we intend to use formal analysis to model and validate the proposaed algorithm.

References

[1] Borko Furht and Armando Escalante, *Handbook of Cloud Computing*, Springer, 2010.

[2] Shabnam Khan, "A survey on scheduling based resource allocation in cloud computing," *International Journal For Technological Research In Engineering*, vol. 1, no. 1, 2013.

[3] K.C. Okafor, F.N. Ugwoke, A.A. Obayi, V.C. Chijindu, and O.U. Oparaku, "Analysis of cloud network management using resource allocation and task scheduling services," *International Journal of Advanced Computer Science and Applications*, vol. 7, no. 1, pp. 375–386, 2016.

[4] VP Anuradha and D Sumathi, "A survey on resource allocation strategies in cloud computing," in *International Conference on Information Communication and Embedded Systems*. IEEE, 2014, pp. 1–7.

[5] V Vinothina, R Sridaran, and Padmavathi Ganapathi, "A survey on resource allocation strategies in cloud computing," *International Journal of Advanced Computer Science and Applications*, vol. 3, no. 6, pp. 97–104, 2012.

[6] Artan Mazrekaj, Isak Shabani, and Besmir Sejdiu, "Pricing schemes in cloud computing: An overview," *International Journal of Advanced Computer Science and Applications*, vol. 7, no. 2, pp. 80–86, 2016.

[7] Sunilkumar S Manvi and Gopal Krishna Shyam, "Resource management for infrastructure as a service (iaas) in cloud computing: A survey," *Journal of Network and Computer Applications*, vol. 41, pp. 424–440, 2014.

[8] Edward Walker, Walter Brisken, and Jonathan Romney, "To lease or not to lease from storage clouds," *Computer*, vol. 43, no. 4, pp. 44–50, 2010.

[9] Rajkumar Buyya, Rajiv Ranjan, and Rodrigo N Calheiros, "Intercloud: Utility-oriented federation of cloud computing environments for scaling of application services," in *Algorithms and architectures for parallel processing*, pp. 13–31. Springer, 2010.

[10] Zhen Xiao, Weijia Song, and Qi Chen, "Dynamic resource allocation using virtual machines for cloud computing environment," *IEEE Transactions on Parallel and Distributed Systems*, vol. 24, no. 6, pp. 1107–1117, 2013.

[11] Anil Singh, Kamlesh Dutta, and Avtar Singh, "Resource allocation in cloud computing environment using ahp technique," *International Journal of Cloud Applications and Computing*, vol. 4, no. 1, pp. 33–44, 2014.

[12] Jorge Ejarque, Javier Álvarez, Raül Sirvent, and Rosa M Badia, "Resource allocation for cloud computing: A semantic approach," *Open Source Cloud Computing Systems: Practices and Paradigms: Practices and Paradigms*, p. 90, 2012.

[13] Daji Ergu, Gang Kou, Yi Peng, Yong Shi, and Yu Shi, "The analytic hierarchy process: task scheduling and resource allocation in cloud computing environment," *The Journal of Supercomputing*, vol. 64, no. 3, pp. 835–848, 2013.

[14] Yujia Ge and Guiyi Wei, "Ga-based task scheduler for the cloud computing systems," in *International Conference on Web Information Systems and Mining*. IEEE, 2010, vol. 2, pp. 181–186.

[15] Joanna Kołodziej, Samee Ullah Khan, Lizhe Wang, and Albert Y Zomaya, "Energy efficient genetic-based schedulers in computational grids," *Concurrency and Computation: Practice and Experience*, vol. 27, no. 4, pp. 809–829, 2015.

[16] Sagnika Saha, Souvik Pal, and Prasant Kumar Pattnaik, "A novel scheduling algorithm for cloud computing environment," in *Computational Intelligence in Data Mining, Volume 1*, pp. 387–398. Springer, 2016.

[17] Georgios C Chasparis, Martina Maggio, Enrico Bini, and Karl-Erik Årzén, "Design and implementation of distributed resource management for time-sensitive applications," *Automatica*, vol. 64, pp. 44–53, 2016.

[18] Dinesh Prasad Sahu, Karan Singh, and Shiv Prakash, "Resource allocation and provisioning in computational mobile grid," *International Journal of Applied Evolutionary Computation*, vol. 6, no. 2, pp. 1–24, 2015.

[19] Karthik Kumar, Jing Feng, Yamini Nimmagadda, and Yung-Hsiang Lu, "Resource allocation for real-time tasks using cloud computing," in *International Conference on Computer Communications and Networks*. IEEE, 2011, pp. 1–7.

[20] Zhen Kong, Cheng-Zhong Xu, and Minyi Guo, "Mechanism design for stochastic virtual resource allocation in non-cooperative cloud systems," in *IEEE International Conference on Cloud Computing*. IEEE, 2011, pp. 614–621.

[21] Paul Marshall, Kate Keahey, and Tim Freeman, "Elastic site: Using clouds to elastically extend site resources," in *IEEE/ACM International Conference on Cluster, Cloud and Grid Computing*. IEEE Computer Society, 2010, pp. 43–52.

[22] Daniel Gmach, Jerry Rolia, and Lucy Cherkasova, "Satisfying service level objectices in a self-managing resource pool," in *IEEE International Conference on Self-Adaptive and Self-Organizing Systems*. IEEE, 2009, pp. 243–253.

[23] Atsuo Inomata, Taiki Morikawa, Minoru Ikebe, Yoshihiro Okamoto, Satoru Noguchi, Kazutoshi Fujikawa, Hideki Sunahara, and Sk Md Mizanur Rahman, "Proposal and evaluation of a dynamic resource allocation method based on the load of vms on iaas," in *IFIP International Conference on New Technologies, Mobility and Security*. IEEE, 2011, pp. 1–6.

[24] Fei Teng and Frédéric Magoulès, "A new game theoretical resource allocation algorithm for cloud computing," in *Advances in Grid and Pervasive Computing*, pp. 321–330. Springer, 2010.

[25] Guiyi Wei, Athanasios V Vasilakos, Yao Zheng, and Naixue Xiong, "A game-theoretic method of fair resource allocation for cloud computing services," *The journal of supercomputing*, vol. 54, no. 2, pp. 252–269, 2010.

[26] Zhanjie Wang and Xianxian Su, "Dynamically hierarchical resource-allocation algorithm in cloud computing environment," *The Journal of Supercomputing*, pp. 1–19, 2015.

[27] Fengyu Guo, Long Yu, Shengwei Tian, and Jiong Yu, "A workflow task scheduling algorithm based on the resources' fuzzy clustering in cloud computing environment," *International Journal of Communication Systems*, vol. 28, no. 6, pp. 1053–1067, 2015.

[28] Dorian Minarolli and Bernd Freisleben, "Virtual machine resource allocation in cloud computing via multi-agent fuzzy control," in *International Conference on Cloud and Green Computing*. IEEE, 2013, pp. 188–194.

[29] Wei-Yu Lin, Guan-Yu Lin, and Hung-Yu Wei, "Dynamic auction mechanism for cloud resource allocation," in *IEEE/ACM International Conference on Cluster, Cloud and Grid Computing*. IEEE, 2010, pp. 591–592.

[30] Hong-Yi Chang, Hsin-Che Lu, Yu-Huei Huang, Yuan-Wei Lin, and Yih-Jou Tzang, "Novel auction mechanism with factor distribution rule for cloud resource allocation," *The Computer Journal*, p. bxt008, 2013.

[31] Maryam Fayazi, Mohammad Reza Noorimehr, and Sayed Enayatollah Alavi, "Resource allocation in cloud computing using imperialist competitive algorithm with reliability approach," *International Journal of Advanced Computer Science and Applications*, vol. 7, no. 3, pp. 323–331, 2016.

[32] Parnia Samimi, Youness Teimouri, and Muriati Mukhtar, "A combinatorial double auction resource allocation model in cloud computing," *Information Sciences*, 2014.

[33] Chonho Lee, Ping Wang, and Dusit Niyato, "A real-time group auction system for efficient allocation of cloud internet applications," *IEEE Transactions on Services Computing*, vol. 8, no. 2, pp. 251–268, 2015.

[34] Amjad Gawanmeh and Ahmad Alomari, "Challenges in formal methods for testing and verification of cloud computing systems," *Scalable Computing: Practice and Experience*, vol. 16, no. 3, pp. 321–332, 2015.

A Proposed Textual Graph Based Model for Arabic Multi-document Summarization

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***Abstract*—Text summarization task is still an active area of research in natural language preprocessing. Several methods that have been proposed in the literature to solve this task have presented mixed success. However, such methods developed in a multi-document Arabic text summarization are based on extractive summary and none of them is oriented to abstractive summary. This is due to the challenges of Arabic language and lack of resources. In this paper, we present a minimal language-dependent processing abstractive Arabic multi-document summarizer. The proposed model is based on textual graph to remove multi-document redundancy and generate coherent summary. Firstly, the original text, highly redundant and related multi-document, will be converted into textual graph. Next, graph traversal with structural rules will be applied to concatenate related sentences to single ones. Finally, unwanted and less weighted phrases will be removed from the summarized sentences to generate final summary. Preliminary results show that the proposed method has achieved promising results for multi-document summarization.**

Keywords*—*Text Summarization; Arabic Abstractive Summary; Textual Graph; Natural Language Processing;

I. Introduction

The increasing amount of data on the Internet today has led to various trends towards automatic text summarization tools. There are two types of text summarization, Extractive and Abstractive. Extractive summarization aims to select important sentences from the original text and organize these sentences to generate a summary. On the other hand, Abstractive summarization attempts to generate human-like summary and may even produce new sentences. This means that the important ideas in the original text are rewritten to generate coherent summaries. Abstractive methods require a more sophisticated process, involving information fusion, sentence compression, and/or language generation [1]. Due to the difficulty associated with the generation of abstracts, most text summarization techniques only focus on the first type.

According to the literature, great works have been made to build a text summarization system for English language. However, few of these have targeted Arabic language. Moreover, all existing work in Arabic multi-document Summarization used Extractive techniques [2]. This lack or absence of such systems is due to challenges presented by the Arabic language.

Arabic is an inflectional, morphologically complex, highly derivational language. Moreover, Arabic is rich in the use of affixes and clitics and, usually, disambiguating short vowels and other orthographic diacritics in standard orthography are omitted [3]. In addition, for text summarization there is absence of automatic and manual Arabic gold-standard summaries and lack of Arabic natural language processing resources like text generators, corpora, machine-readable dictionaries, lexicons and ontologies.

There are two types of documents to be summarized, single and multi-document. Single document summarization produces summary for one document about a specific subject whereas multi-document summarization aims to generate a single summary of a group of related documents. Online user reviews, tweets in Twitter and comments in YouTube or Facebook websites are the most prominent examples of multi-documents.

The problem with Extractive methods in multi-document summarization is that it should select only the most important sentences along the related documents. This means that there are several sentences that beneficial meanings to be conveyed could be missed in the final summary. To address this problem we proposed a minimal language-dependent processing Abstractive Arabic summarization model. Our model aims to remove the redundancy from highly redundant multi-documents and concatenate the related documents to a single one.

The rest of this paper is organized as follows: Section 2 presents the previous work; Section 3 presents the proposed model; in Section 4 we discuss the evaluation and experimental results; finally, in Section 5, we introduce the conclusion of our work and propose some future work.

II. Previous Work

In English language several pieces of research have been proposed in Text summarization. We are interested in multi-document abstractive summarization approaches that almost can be applied to Arabic language.

In [4] K Ganesan et al. proposed multi-document abstractive text summarizer. The system used a graph data structure that relied on the structural redundancies in the text to discover informative phrases. This work known as Opinosis used graph to get all possible sentences related to a specific query. In [5] Hai-Tao et al. the original text was converted into textual graph and they got the final summary by applying English text syntax rules.

A recent work in [6] Liu et al. have proposed a model that focused on the graph-to-graph transformation to generate abstractive summary. They mapped the source text into

Abstract Meaning Representation (AMR) graphs, and then transformed them into a summary graph to generate final summary. In [7] L Bingis et al. proposed method that generates new sentences by extracting noun phrases and verb-object phrases from the documents. They generate the final summary by merging informative phrases to new sentences.

Multi-document summarization in Arabic language is still in its infancy compared to the literature on English [8] and all existing work use extractive techniques.

In [9] KSAL Harazin et al. used a single document summarization approaches for multi-document summarization, also they provided a model for multi-document summarization that relied on cross document structure theory. In [10] El-Haj and Rayson proposed extractive language-independent summarizer for single and multi-document. A corpus-based technique for both English and Arabic language was applied. They compared lists of word frequencies between two corpora in both languages to compute the log-likelihood score for each word. Summaries were built by selecting sentences that had the highest log-likelihood scores.

In [11] Oufaida et al. presented summarization system for a single and multi-document. In the proposed system, the sentences to be summarized were selected based on the ranks of their terms. To extract summary sentences, the system ranked the terms by using the minimal-redundancy maximal-relevance method (mRMR) [12] and clustering algorithm.

For Abstractive Arabic text summarization, S.Ismail et al. [13] are working on single document summarization. Their proposed system consisted of three modules, first they convert the input Arabic text into a semantic graph called Rich Semantic Graph (RSG). The second and third modules of this proposed model are, performing graph reduction and generating the summary from the reduced graph, respectively.At the present time this research still ongoing.

III. Proposed Model

The proposed model to remove text redundancy and generate Abstractive Arabic text summary consists of 4 stages as shown in Figure 1: 1. Preprocessing to remove text noises. 2. Representing the multi-documents by directed weighted graph. 3. Traversing the graph and applying structural rules to generate the summary sentences. 4. Refining the sentences which contain unwanted parts and adding them into the final summery.

A. Preprocessing

In order to map the original multi-documents into the textual graph, it is preferable to remove a different set of attachable punctuation, diacritics, prefixes and suffixes from the word. For Arabic text Preprocessing we use AraNLP [14] which is a free Java-based library that covers various text preprocessing tools.

Diacritics removal: It removes three forms of diacritics, the Shadda, Nunation Diacritics and Vowel Diacritics. *Punctuation removal*: this tool has been used to remove number of punctuations like Arabic semi-colons (؛), commas (,), Arabic exclamation marks (!), Arabic question marks (؟). *Light stemmer*: this

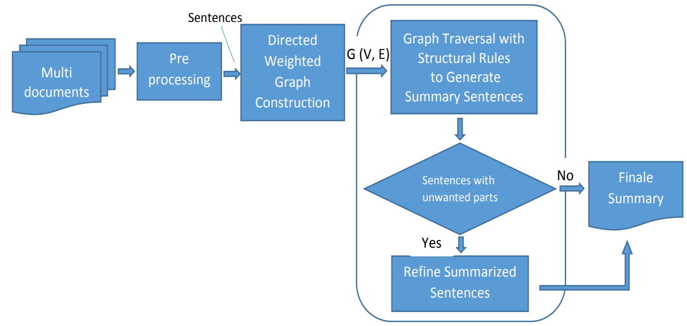

Fig. 1: Overview for the Proposed Model.

is the most important tool, it has been used to remove suffixes and prefixes from the original word. For example, ”الجهاز“ and ”جهاز“ have the same conceptual meaning and should map into one word ”جهاز“. This tool significantly helps to reduce the amount of the processed text. *Stop word recognition*: In this step we do not use AraNlp stop words removal to remove stop words, instead we use it to determine if the word is a stop word or not. The stop words are any word without semantic meanings and are used as an auxiliary words in the sentence, such as ”من“, ”على,”ان“, ”في“. Finally we determine the part of speech, using POS-tagger, for each single word using stanford Arabic word segmenter and POS tagger [15].

B. Constructing the Directed Weighted Graph

Our work exploits textual graph and attempts to enrich Arabic text summarization by new technique in Abstractive summary. Graphs have been commonly used for extractive summarization for example, LexRank by G Erkan et al. [16] and TextRank by R Mihalcea et al. [17] and also for Abstractive summarization for example, Opinosis by K Ganesan et al. [4]. Constructing the textual graph is similar to Opinosis with some differences.

To construct the graph $G(V, E)$, the unique stem (light stemming) for every word in the original multi-documents should map into single node or vertex (V) in the graph. Words with the same stem should map into the same node. The graph is a directed graph where the edge (E) between two nodes (words) in the graph indicates the adjacency (sequential flow) relationship between those words in the sentence. Unlike Opinosis, every stop-word in the original text should map into a single node. To ensure that each node has a unique word, sentence index and word index should attach into every stop-word. The textual graph construction could be summarized as follows:

- For each word:
  - Check:
    - If it is in graph, then do nothing.
  - Otherwise check:
    - If it has adjacent word in the graph, then it becomes next or previous node.
  - Otherwise:

- The word should map into a new initial node that will connect to its potential neighbors.

Figure 2 is an illustration of a simple textual graph construction. The node that contains word mentioned several times through the document, has several next adjacent nodes. For example the word "التابلت" (the red node) has 4 nodes directly connected to it. However, for a word that occurs in a single sentence should has one next adjacent node. Inherently, the graph removes redundancy from the text so the same words in different sentences are mapped into one node in the graph.

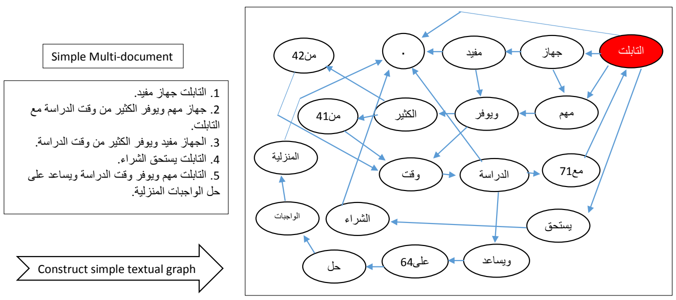

Fig. 2: Simple high redundant text converts into textual graph.

Node Attributes and Weight:

Each node in the graph should keep nine attributes, the original word, word stem, word type, word index, sentence index, sentence length, part of speech tag, word frequency and sentence weight. The word type either stop-word or unstop-word. Sentence index and word index are sentence id in the document and word position in this sentence respectively. For word that occurs in several sentences the node keeps only the id of the first sentence in which this word appears and that is true for the word position as well. Sentence length is the number of tokens (words) in the sentence. Node also keeps part of speech tag for each word either noun, verb, adjective, etc. The weight attribute can be calculated using the following equation:

$$TotalWeight = \frac{1}{m}\sum_{i=1}^{m} W \tag{1}$$

Where m is the length of the sentence and W is the weight of word that can be calculated from the following equation:

$$W = TFIDF * POS * StopWord \tag{2}$$

Where

$$TFIDF = N(1 + log\frac{D}{n}) \tag{3}$$

Where N is the frequency of the word in the multi-document, D is the total number of documents (sentence) and n is the documents that contain this word. POS , empirically, gives 1 for nouns, 0.6 for verbs and 0.3 for others. $StopWord$ is 0 for any stop-word and 1 for others.

C. Graph traversal with Structural Rules to Generate Summary Sentences

We want to generate summary sentences of that have high redundancy (thus summarize the major meaning). Up till now, the graph has removed the redundancy. We need extract the new summarized sentences out of the graph. Depth first traversal search along with structural rules have been used to do as follows:

1) First, we retrieve the words according to their sequence in the original sentences. For this step word index and sentence index should be checked.
2) Mark every node (word) added to the summary as visited.
3) Check if the word has several next neighbors, then this means that there are several related sub-sentences that could be concatenated together and form a new sentence. For example: the word "التابلت" in the simple graph in figure 2 has four next adjacent nodes, so, there are four sub-sentences related to this word that could be concatenated together to form a new sentence. Each sub-sentence should begin by next adjacent node and ends by either full-stop or visited node.
4) Check if the node has no previous node and the next has already been marked as visited then ignore it. This means that the current node (word) is not important enough and it should be avoided to be added to the summary. This leads to reducing the size of the final summary.
5) Check if the node is a stop-word and its next adjacent node has been visited then ignore it. This means that this node is a terminal stop-word and has no meaning to add to the summary.

D. Refining Summarized Sentences and Generating the Summary

At the end of graph traversal we end up with three types of sentences:

1) Sentences that result from merging sentences or sub-sentences together.
2) Sentences that are trimmed from original sentences after unwanted word(s) has/have been removed or sentences that part(s) of them has/have been added to the merged sentences.
3) Sentences without any change in their original body.

In order to make sure that sub-sentences or trimmed sentences have enough meaning to add to the summary the following conditions have been applied:

1) Check if sub-sentence or trimmed sentence weight is greater than a specific threshold t, then it will be included in the summary. Experimentally:

$$t = \frac{1}{6}(TotalWeight) \tag{4}$$

Such that $TotalWeight$ is the weight of the original sentence (equation 1).
2) Check if sub-sentence or trimmed sentence contains more than four words and its weight is less than the

threshold, then add to the summery. This means that the original sentence is too long and the part which we have trimmed out of it conveys enough meaning to be added to the final summary.

3) Avoid adding to the summery those sub-sentences or trimmed sentences that contain only single word or single word with stop word only.

For the simple graph in figure 2 the new summary is:

التابلت جهاز مفيد ويوفر الكثير من وقت الدراسة ويساعد على حل الواجبات المنزلية يستحق الشراء.

IV. Results and Discussion

Text summarization is a very important issue. According to (Lloret et al. 2012) [18] the evaluation of automatic summarization represents a challenging area. However, the summary that obtained from our model has the properties of abstractive summary and, as mentioned in section 1, there is no previous work in Arabic abstractive text summarization. Moreover, the type of data set that have been used to work with (opinions or user reviews) has not used before for Arabic text summarization. This means that, there is no previous works or technologies to compare with. For this reason, to be able to evaluate our model results we went through two ways: manually by recruiting human reviewers and automatically by compare the amount of meaning in the summaries with the amount of meaning in the original multi-documents.

The dataset that has been used to experiment the proposed model was collected from the well-known online shopping website [1] and Twitter.com. Users reviews about twenty-five different products (mobile cell phones and tablets) and tweets talked about five different subjects was crawled from the first and the second websites respectively. We are following multi-document summarization approach where the total number of documents that we have used are 1651 documents grouped into 30 multi-documents.

For the test, 1651 documents have been inserted to the system as input and it generate 441 sentences as summary. Then, the first 293 summarized sentences obtained to five educated users. The users were then asked to tell how much they agreed with the following statement: ''this is a correct and meaningful sentence''. The volunteers then were asked to rate their degree of satisfaction on a 5-point Likert scale where 1 indicates strong unsatisfaction and 5 indicates strong satisfaction.

Figure 3 shows the average results for the five scales. The Likert scale results of the criteria ''this is correct and meaningful sentence'' shows that the raters agree with that 72% of the summarized sentences are correct and meaningful.

Table [1] shows a comparison between the original documents and their associated summery for 30 multi-documents. ''Original Sentences'' column contains the total number of sentences in each multi-document while ''Summary Sentences'' column contains the number of summarized sentences. ''Reduction Ratio'' column presents the proportion of summary sentences to the multi-document sentences. ''Meaning Amount'' column presents the proportion of meaning conveyed by summary to the total meaning in the original multi-document.

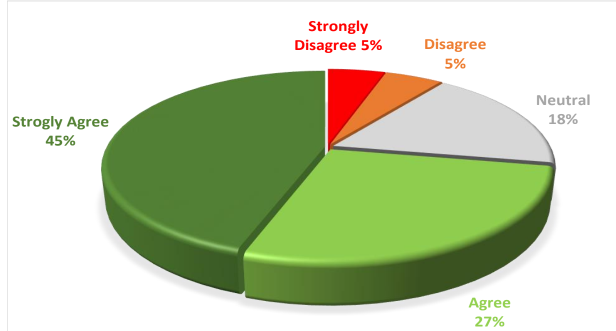

Fig. 3: Results of criteria: ''this is correct and meaningful sentence'' scales.

Multi-Document	Original Sentences	Summary sentences	Reduction Ratio	Meaning Amount
d1	19	8	0.58	0.77
d2	37	15	0.59	0.66
d3	53	15	0.72	0.64
d4	21	8	0.62	0.78
d5	66	19	0.71	0.61
d6	39	9	0.77	0.56
d7	37	15	0.59	0.51
d8	37	9	0.76	0.71
d9	29	9	0.69	0.72
d10	62	21	0.66	0.59
d11	31	8	0.74	0.75
d12	51	14	0.73	0.64
d13	70	11	0.84	0.58
d14	70	20	0.71	0.62
d15	23	6	0.74	0.69
d16	60	19	0.68	0.62
d17	51	27	0.47	0.62
d18	55	22	0.6	0.63
d19	85	28	0.67	0.61
d20	30	10	0.67	0.7
d21	45	18	0.6	0.72
d22	131	27	0.79	0.68
d23	57	11	0.81	0.74
d24	34	5	0.85	0.74
d25	66	12	0.82	0.68
d26	83	10	0.88	0.7
d27	98	20	0.8	0.71
d28	89	20	0.78	0.73
d29	78	15	0.81	0.76
d30	44	10	0.77	0.63

Table 1: A comparison between the original documents and their associated summery for 30 multi-documents

Weight of a document calculated using the following equation:

$$Weight = \frac{1}{n}\sum_{i=1}^{n}(sentenceWeight) \quad (5)$$

where $sentenceWeight$ calculated from equation (1) and n is the total number of sentence in a document. Therefore, weight for both the original document and the summary is

[1] egypt.souq.com/eg-ar

calculated and the meaning amount conveyed by summary is obtained as follows:

$$MeaningAmount = \frac{summaryWeight}{originalDocumentWeight} \quad (6)$$

We have found that the system reduces the original text at an average to 28%. Meanwhile, it keeps in average 67% of the general meaning in the summarized version. This is reasonable because we are only interested in parts with high redundancy along the multi-document. From Table [1], the summary of multi-document (d26) and (d17) are the maximum and minimum reduction respectively.

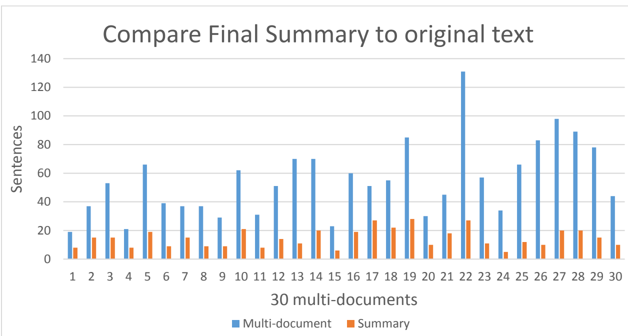

Fig. 4: The proportion of summary sentences to the original multi-document sentences.

V. Conclusion and Future Works

We have proposed a minimal language-dependent processing abstractive Arabic text summarization rule based model. This model depends on textual graph to remove text redundancy and constructs new sentences by concatenate related sentences together.

The proposed model consists of four stages namely; preprocessing, representing the multi-documents by directed weighted graph, traversing the graph and finally applying structural rules to generate summarized sentences.

The proposed model has achieved promising results for multi-document summarization. From the experiment using sample documents reached to 88% reduction ratio.

The future work could be include semantic process to enhance the summarization model. Also, we can add dictionaries, lexicons and ontologies to this model which maybe maximize the reduction ratio and could lead to generate highly readable and meaningful summary.

References

[1] E. Lloret and M. Palomar, "Analyzing the use of word graphs for abstractive text summarization," in *Proceedings of the First International Conference on Advances in Information Mining and Management, Barcelona, Spain*, 2011, pp. 61–6.

[2] A. B. Al-Saleh and M. E. B. Menai, "Automatic arabic text summarization: a survey," *Artificial Intelligence Review*, vol. 45, no. 2, pp. 203–234, 2016.

[3] N. Habash and O. Rambow, "Arabic tokenization, part-of-speech tagging and morphological disambiguation in one fell swoop," in *Proceedings of the 43rd Annual Meeting on Association for Computational Linguistics*. Association for Computational Linguistics, 2005, pp. 573–580.

[4] K. Ganesan, C. Zhai, and J. Han, "Opinosis: a graph-based approach to abstractive summarization of highly redundant opinions," in *Proceedings of the 23rd international conference on computational linguistics*. Association for Computational Linguistics, 2010, pp. 340–348.

[5] H.-T. Zheng and S.-Z. Bai, "Graph-based summarization without redundancy," in *Web Technologies and Applications*. Springer, 2014, pp. 449–460.

[6] F. Liu, J. Flanigan, S. Thomson, N. Sadeh, and N. A. Smith, "Toward abstractive summarization using semantic representations," 2015.

[7] L. Bing, P. Li, Y. Liao, W. Lam, W. Guo, and R. J. Passonneau, "Abstractive multi-document summarization via phrase selection and," *arXiv preprint arXiv:1506.01597*, 2015.

[8] M. El-Haj, U. Kruschwitz, and C. Fox, "Exploring clustering for multi-document arabic summarisation," in *Information Retrieval Technology*. Springer, 2011, pp. 550–561.

[9] K. S. A. Harazin, "Multi-document arabic text summarization," Ph.D. dissertation, Islamic University, Gaza, Palestine, 2015.

[10] M. El-Haj and P. Rayson, "Using a keyness metric for single and multi document summarisation." Association for Computational Linguistics, 2013.

[11] H. Oufaida, O. Nouali, and P. Blache, "Minimum redundancy and maximum relevance for single and multi-document arabic text summarization," *Journal of King Saud University-Computer and Information Sciences*, vol. 26, no. 4, pp. 450–461, 2014.

[12] H. Peng, F. Long, and C. Ding, "Feature selection based on mutual information criteria of max-dependency, max-relevance, and min-redundancy," *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, vol. 27, no. 8, pp. 1226–1238, 2005.

[13] S. S. Ismail, M. Aref, and I. F. Moawad, "A model for generating arabic text from semantic representation," in *2015 11th International Computer Engineering Conference (ICENCO)*. IEEE, 2015, pp. 117–122.

[14] M. Althobaiti, U. Kruschwitz, and M. Poesio, "Aranlp: a java-based library for the processing of arabic text," 2014.

[15] M. Diab, K. Hacioglu, and D. Jurafsky, "Automatic tagging of arabic text: From raw text to base phrase chunks," in *Proceedings of HLT-NAACL 2004: Short papers*. Association for Computational Linguistics, 2004, pp. 149–152.

[16] G. Erkan and D. R. Radev, "Lexrank: Graph-based lexical centrality as salience in text summarization," *Journal of Artificial Intelligence Research*, pp. 457–479, 2004.

[17] R. Mihalcea and P. Tarau, "Textrank: Bringing order into texts." Association for Computational Linguistics, 2004.

[18] E. Lloret and M. Palomar, "Text summarisation in progress: a literature review," *Artificial Intelligence Review*, vol. 37, no. 1, pp. 1–41, 2012.

An Auction-Bidding Protocol for Distributed Bit Allocation in RSSI-based Localization Networks

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***Abstract*—Several factors (e.g., target energy, sensor density) affect estimation error at a point of interest in sensor networks. One of these factors is the number of allocated bits to sensors that cover the point of interest when quantization is employed. In this paper, we investigate bit allocation in such networks such that estimation error requirements at multiple points of interest are satisfied as best as possible. To solve this nonlinear integer programming problem, we propose an iterative distributed auction-bidding protocol. Starting with some initial bit distribution, a network is divided into a a number of clusters each with its own auction. Each cluster head (CH) acts as an auctioneer and divides sensors into buyers or sellers of bits (i.e., commodity). With limited messaging, CHs redistribute bits among sensors, each bit at a time such that the difference between achieved and required estimation errors within each cluster is reduced in each round. We propose two bit-pricing schemes used by sensors to decide on exchanging bits. Finally, simulation results show that our proposed 'distributed' protocol's error performance can be within $5\% - 10\%$ of that of a 'centralized' genetic algorithm (GA) solution.**

***Keywords*—Target localization; Auction-bidding**

I. Introduction

A Distributed sensor network (DSN) consists of a large number of sensors deployed in a region of interest (ROI) with the main task of monitoring certain phenomenon in the ROI [1], [2]. With their ability to continually monitor in harsh and hostile environments with limited human intervention, DSNs bridge the gap between the physical world and our computational world. DSNs have found uses in many fields such as; environmental, industrial, agriculture and defense. However, in many cases it is not sufficient to monitor the phenomenon (e.g., fire) and detect its presence. It might be also necessary to identify the coordinates of the source of the phenomena (i.e., target localization) in order to take meaningful action (e.g., fire control) [3]-[6].

Target localization in general is a nonlinear estimation problem [7]-[9], in which sensors send their nosy data to a fusion center that employs some estimator (e.g., ML estimator) to determine location information. The problem's nonlinearity arises from the nonlinear relationship between sensor measurements (e.g., received signal strength (RSSI) and time difference of arrival (TDOA)) and target location. RSSI measurements are commonly used due to the simplicity of obtaining them in comparison to other types.

In RSSI-based localization, error performance is dependent on several factors. These include; sensor positions with respect to target, target-related parameters (e.g., energy profile), measurement model [10], [11]. Moreover, in practical networks with imposed bandwidth and energy limits, measurement quantization is usually employed. In such a case, the localization error performance further depends on both the number of bits allocated to each sensor and the quantization thresholds used [12].

Due to the complicated relationship between the above mentioned parameters and the error performance, it becomes important to devise intelligent methods for bit allocation in RSSI networks. Furthermore, and due to the large number of sensors typically found in DSN, it is important for bit allocation to be scalable and easy to implement.

We state the problem we study in this paper as follows; Given a network of M sensors deployed in an ROI that contains multiple points of interest with corresponding estimation error requirements and having some given initial bit allocation distribution, how can we re-allocate these bits in a "distributed" fashion such that error requirements at the points of interest are met as best as possible?. To solve this problem, propose a novel distributed bidding/auction protocol for bit re-allocation. Next, we provide an overview of some related works to the bit allocation problem in RSSI-based localization networks.

In [13], an iterative two-stage algorithm for bit allocation and threshold selection is proposed with the goal of minimizing the average overall error. The first stage deals with the reconstruction of the quantized sensor measurement at the fusion center (FC). The second part is concerned with the error between the actual location of the target and its estimated location. We note that the proposed algorithm constructs the quantizer using a training data set according to some given probability distribution of the target's possible location. In addition, the authors propose a simple equal distance divided quantizer (EDQ) for threshold selection, where each quantization interval corresponds to a quantization ring within the sensor field.

More recently, in [14] and [15], the authors propose several bit allocation methods for the target tracking problem with the goal of minimizing estimation error. As a cost function, the authors use the determinant of the Fisher information matrix (FIM). To solve this problem, the authors propose an 'approximate' recursive dynamic programming (A-DP) approach for bit allocation. In addition, a modified version of the Breiman, Friedman, Olshen, and Stone (GBFOS) algorithm is proposed. Both algorithms are shown to have a comparable performance. In [16], the authors devise several bit allocation algorithms to meet error requirements at multiple points within the region of interest rather than a single point which enables the considerations of multiple subregions with different levels of importance. Furthermore, an adaptive thresholding scheme is devised in [16] that incorporates error requirements within a sensor's sensing zone in threshold selection.

We note the algorithms presented in the works above are 'centralized' in nature, that require sensors to send relevant data to a central processor to perform allocation. This centralized approach might not be computationally practical for dense networks with a large number of sensors. In addition, it might result in inadequate performance, especially if requirements are rapidly changing. In contrast, the algorithm we propose in this paper is distributed in nature and requires information exchange between a sensor and the sensors in its immediate neighborhood. The second difference is the fact that in most of these works, error minimization was considered at a single point. This is in contrast to this work, in which the goal is to meet error requirements over an area of interest.

The bit allocation algorithm we propose in this paper is an auction/bidding-type algorithm. As a network become more complicated and the operation of its different components (e.g., sensors) more inter-related, its management becomes more difficult. One important problem that faces such a DSN is resource allocation [17]. One method for solving this problem is auction theory, which has been applied to bandwidth, power and time-slot allocation problems [18]-[20] in communication networks. Auction theory has been applied as well to sensors networks. For example, the authors in [21] propose a bidding protocol for mobile sensors deployment with the goal of maximizing the coverage within a region of interest. In this protocol, static sensors detect coverage holes and estimate their size and send this information to near-by mobile sensors which only relocate to the new location if the improvement in coverage after movement is larger than coverage degradation at the original sensor location. The proposed coverage-maximizing protocol is distributed and is scalable to dense networks.

In this paper, we consider an (ROI) with N points of interest. Each point is assigned a minimum estimation requirement that is to be met. A number M of sensors are deployed, each with an initial number of quantization bits that need not be uniform. It is of interest to reallocate bits such that specified estimation error requirements are met as best as possible. To solve this problem, we propose a novel iterative auction/bidding protocol for bit reallocation. In each iteration/round, the network is divided into clusters, each with its own cluster head (CH). The CH acts as an auctioneer in an auction. The CH then divides sensors in its cluster to either buyers or sellers where the commodity to be exchanged is bits. The pricing policy (i.e., valuation) of bits can be specified in several ways. Here, we propose two valuation policies in terms of two factors; the number of bits that a sensor already uses and the difference between achieved and required estimation requirements within a sensor's sensing radius. The CH deallocates a bit from a seller sensor with the lowest valuation, to the buyer with the highest valuation. Simulation results show that the proposed distributed algorithm can provide a comparable performance to that of a centralized genetic algorithm (GA) solution.

The paper is organized as follows; in Section (II) we discuss the system model and our problem set-up. In Section (III), we introduce the proposed bit allocation methods. Simulation results are discussed in Section (IV) and conclusions are summarized in Section (V).

II. System Model and Problem Formulation

We consider an $2-$D region of interest (ROI) of dimensions $b \times b$ with N points of interest in the ROI. The coordinates of these points are given as $\{\mathbf{p}_n = [x_n, y_n]', n = 1, 2, \dots, N\}$. Minimum estimation error requirements $\{\mathbf{E}_{\text{req}}(n), n = 1, 2, \dots, N\}$ are specified for each point. Using $\mathbf{E}_{\text{req}}$ enables us to divide the ROI into different subregions with varying levels of importance if needed.

The network consists of M static sensors with known positions denoted as $\{\mathbf{s}_m = [x_m, y_m]', m = 1, 2, \dots, M\}$. Sensors are assumed to provide received signal strength indicator (RSSI) measurements which are easier to obtain than other measurement types (e.g.,time of arrival (ToA)) [22], [23].

Let $\mathbf{p}_t = [x_t, y_t]'$ denote the target's position, then the RSSI measurement of the m-th sensor is given as [24], [25]

$$z_m = \sqrt{P_0}\; e^{\frac{-\alpha}{2} d^2_{t,m}} + w_m, \quad m = 1, 2, ..M \qquad (1)$$

where, P_0 denotes the energy emitted by the target and $d_{t,m}$ denotes the distance between the m-th sensor and $\mathbf{p}_t$. The parameter α is a decay factor. The noise w_m is assumed to be i.i.d zero-mean Gaussian ($w_m \sim \mathcal{N}(0, \sigma^2)$).

To reduce energy and bandwidth usage, sensors are assumed to transmit their measurements quantized. Let R_m denote the number of bits used by the m-th sensor and let $\{\eta^l_m, l = 1, 2, \dots, 2^{R_m} - 1\}$ denote its quantization thresholds, then the quantized measurement of the m-th sensor which is denoted as z^{q}_m is mapped as follows

$$z^{\mathrm{q}}_m = \begin{cases} 0 & \text{, if } -\infty < z_m \le \eta^1_m \\ 1 & \text{, if } \eta^1_m < z_m \le \eta^2_m \\ . & \\ . & \\ 2^{R_m} - 1 & \text{, if } \eta^{2^{R_m}-1}_m < z_m \le \infty \end{cases} \qquad (2)$$

Let $\mathbf{E}(n)$ denote the achieved estimation error at the n-th point, then $\mathbf{E}(n)$ quantifies how accurate is the estimator in estimating the location of the target if it were placed at the n-th point. The mean square error $\mathbf{E}(n)$ is defined as

$$\mathbf{E}(n) = \mathrm{E}[(\mathbf{p}_n - \hat{\mathbf{p}_n})(\mathbf{p}_n - \hat{\mathbf{p}_n})^{\mathrm{T}}] \qquad (3)$$

where, $\mathrm{E}[\cdot]$ denotes the expectation operator.

The error $\mathbf{E}(n)$ can be bounded using the Cramer-Rao lower bound(CRLB) [26], [27]. In many cases (e.g., large SNR measurements, dense network), the CRLB can be used as an approximation of the actual estimation error.

In our problem, $\mathbf{E}(n)$ can be bounded using the CRLB as

$$\mathbf{E}(n) \ge \text{Trace } [(\mathbf{J}_n)^{-1}] \qquad (4)$$

where, $\mathbf{J}_n$ is the Fisher information matrix (FIM) corresponding to the n-th point. For the derivation of the FIM matrix for the quantized RSSI measurement model, the reader is referred to [24] and is given as

$$\mathbf{J} = \begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix} \tag{5}$$

where, the FIM elements are given as [24], [25]

$$J_{11} = \sum_m \beta_m (x_n - x_m)^2 \tag{6}$$

$$J_{12} = J_{21} = \sum_m \beta_m (x_n - x_m)(y_n - y_m) \tag{7}$$

$$J_{22} = \sum_m \beta_m (y_n - y_m)^2. \tag{8}$$

The parameter β_m is given as

$$\beta_m = \frac{\alpha^2 P_0 e^{-\alpha d^2_{m,n}}}{2\pi\sigma^2}\gamma_m \tag{9}$$

where λ_m and γ_m are given as

$$\lambda_m = \frac{\alpha^2 P_0 e^{-\alpha d^2_{m,n}}}{2\pi\sigma^2} \tag{10}$$

and

$$\gamma_m = \sum_l \frac{1}{p^l_m}[e^{\frac{-(\eta^l_m - a_m)^2}{2\sigma^2}} - e^{\frac{-(\eta^{l+1}_m - a_m)^2}{2\sigma^2}}]^2 \tag{11}$$

where, p^l_m is the probability that the quantized measurement z^{q}_m takes on the value l and is given as

$$p^l_m = \Pr(z^{\mathrm{q}}_m = l) \tag{12}$$

$$= Q(\frac{\eta^l_m - a_m}{\sigma}) - Q(\frac{\eta^{l+1}_m - a_m}{\sigma}). \tag{13}$$

Based on the equations above (Eqns.(6)-(11)), that the estimation error depends on several parameters (e.g., P_0, α and σ^2). We also note that a sensor's contribution to reduction of error at a point is inversely proportional with the distance separating it from the point of interest. Finally, we note that the number of quantization bits and thresholds are incorporated in the γ_m parameter in Eqn. (11). In general, the more bits allocated combined with an intelligent choice of quantization intervals results in increase of the sensor's contribution to estimation error reduction.

Thus, it is evident that the distribution of bits within the ROI is an important factor in determining the overall error performance of the network. An informed allocation of bits is especially important for networks deployed in areas with different estimation requirements. It is also critical in the case of varying requirements or network topology (e.g., death or malfunction of sensors) in which loss of bits needs to be compensated.

The problem we study in this paper can be stated mathematically as follows

$$\begin{aligned} \underset{\mathbf{R}}{\text{minimize}} \quad & \sum_{n=1}^{N} (\mathbf{E}_{\text{req}}(n) - \mathbf{E}(n))^2 \\ \text{subject to} \quad & \mathbf{R} \succeq \mathbf{0}, \\ & \sum_{m=1}^{M} R_m = R_T, \end{aligned} \tag{14}$$

where, $\mathbf{R} = [R_1, R_2, \ldots, R_m]$ is the vector of the number of bits allocated to each sensor and R_T is the total number of bits.

The allocation problem in Eqn. (14) is an integer nonlinear programming problem. Because of its computational complexity, especially for dense networks, it is desirable to develop computationally tractable algorithms for solving such a problem.

One important note is the fact that the estimation error achieved at some points might not be defined. Localization in 2-D setups requires that a point be covered (i.e., within the sensing radius of a sensor) with at least 3 sensors. Hence, if a point is covered by less than 3 sensors, then regardless of how many bits are allocated to the sensors covering it there will be no meaningful achieved estimation error. We denote this as having $\mathbf{E}(n) = \infty$. To alleviate this problem, we propose the following logarithmic error definition [16]

$$\mathbf{E}^L(n) = \log(1 + \frac{1}{\mathbf{E}(n)}) \tag{15}$$

which solves the problem of dealing with errors. Hence, we can consider modifying the objective function in Eqn. 14 to be in terms of the logarithmic errors.

We next present a distributed protocol for solving the above mentioned allocation problem.

III. Proposed Allocation Protocol

The bit allocation problem in RSSI localization is difficult due to the nonlinearity between achieved estimation error and the number of bits allocated to a sensor. This is in addition to the error dependence on the actual quantization thresholds used. Another factor is the dependence of estimation error at one point on not only on a single sensor, but on the total number of sensors covering this point along with their quantization bits and thresholds. We later refer to this dependence as the coupling problem.

To solve this problem we next outline our proposed bit allocation protocol.

A. Proposed Protocol

To establish an auction, we need several elements; sellers, buyers, auctioneer and commodities to be exchanged with certain prices and revenues. To attain these elements, we divide the network into several clusters, each with its own cluster head (CH). Sensors in each cluster participate as either sellers or buyers with the CH acting as an auctioneer. To reduce communication costs, the CH (i.e., auctioneer) collects data about possible sellers and buyers in its cluster and makes the allocation decision. Using some bit valuation (i.e., a pricing scheme which will be discussed later), a sensor is to deallocate a bit (i.e., sell) to another sensor in its cluster if it produces a better overall network valuation (e.g., error performance) than if bit were to be kept by the sensor. Similarly, a sensor is permitted to use an additional bit (i.e., buy), that has been deallocated from another sensor, if it produces a better overall network valuation. To reduce communication cost between sensors, communication is restricted to the CH. The proposed protocol can be outlined as follows

1) The CH calculates its own selling price according to the specified scheme and transmits its price to its cluster nodes.
2) Each sensor locally calculates its own selling price and those with a price lower than that of the CH identify themselves as sellers and inform the CH of their status and price.
3) Next, the CH calculates its buying price and transmits it to cluster sensors.
4) Sensors locally calculate their buying price and compare to that of the CH. Sensors with a higher buying price than that of the CH identify as buyers and similarly send their information to the CH.
5) The CH then deallocates a bit from the sensor with the lowest selling price and allocates it to the sensor with the highest buying price.
6) Repeat the above steps as much as specified by the user.

In addition to being an auctioneer, the CH acts as a possible buyer or seller. This is true since it provides a ceiling on the selling price and a floor on the buying price which is useful for limiting unnecessary communication.

Notes:

1) The selection of CHs can be achieved using a cluster head selection algorithm. A popular approach is using the LEACH algorithm which is employed in this paper [28], [29]. Using this algorithm, a sensor (s) generates a random number between 0 and 1. If this number is less than a certain threshold $T(s)$, then the sensor becomes a CH for this round. The threshold $T(s)$ is given as [28], [30]
$$T(s) = \begin{cases} \frac{p_{\text{CH}}}{1-p_{\text{CH}}(r \mod \frac{1}{p})} & \text{if } s \in G \\ 0 & \text{else} \end{cases} \quad (16)$$
where, $p_{\text{CH}},\ r,\ G$ represent, respectively, the desired percentage of cluster-heads, the current round number, and the set of nodes that have not been cluster-heads in the last $1/p_{\text{CH}}$ rounds. We note that $p_{\text{CH}} = \frac{C}{M}$, where C is the number of CHs to be selected. Sensors closer to a CH join the cluster corresponding to this CH.
2) One problem resulting from the coupling of error performance is the collision problem. We define the collision problem in this context as the problem of interfering sensors whose sensing zones (i.e., disc of radius R_s) overlap with the domains of other sensors that fall within another cluster. Under such situation, CHs of two adjacent clusters might deallocate bits from neighboring sensors concurrently. This might produce a change in estimation errors more than the one reported by sensors to be their selling price, which can not be matched by improvement in estimation error reported by the winning sensor. On the other hand, bits can be allocated concurrently to adjacent sensors from two clusters which causes over-meeting estimation requirements at some area while requirements at other areas are not met.
To solve this problem, it is possible to force the CHs to be a certain distance away from each other such that sensors that belong to a cluster do not have overlapping domains with sensors that belong to other clusters. If R_{CH} and R_s denote the clustering and sensing radii respectively, then the distance between CHs $R_{\Delta\text{CH}}$ that eliminates the collision problem should be such that
$$R_{\Delta\text{CH}} \geq 2(R_{\text{CH}} + R_s) \quad (17)$$
We note that using a smaller $R_{\Delta\text{CH}}$, does not necessarily mean that collision will always happen as this depends on sensor positions within the clusters. However, it implies that randomly-occurring degradations in estimation performance are possible. One problem with this approach that it sets a bound on the number of clusters (i.e., auctions) that can be formed in each iteration resulting in a slow reduction of estimation errors. Furthermore, it produces varying number of CHs in each round.
3) The collision problem can also affect bidding in the same cluster, especially when a sensor evaluates bits assuming neighboring sensors are to keep their bits fixed. Assume a sensor submits its selling price and is chosen as a seller. Furthermore, assume the winning sensor's domain overlaps that of the selling sensor. Under this setup, the improvement in estimation error is likely less than what was anticipated by the winning sensor. Thus a lower bidding price might have been more suitable (i.e., another sensor could have won). Different methods can be used to solve the above problem. For example, sensors can calculate their valuations taking into account changes (i.e., increase or decrease) in number of bits at neighboring sensors. However, this comes at the expense of increased computational complexity. Another method, that is employed in this paper, is for each selling sensor to exclude overlapping sensors (i.e., sensors less than R_s away) from the pool of its possible buyers.
4) With no constraints on the number of bits that a sensor can have, a sensor might end up selling all its bits. Thus, the sensor will not report any measurements resulting in a coverage loss (i.e., as if the sensor does not exist when calculating actual estimation errors). One possible solution is for a sensor to stop participation in selling when it has one bit left.

B. Bit Valuation

We propose two possible bit valuation (i.e., pricing schemes) methods that require a limited amount of message passing. These schemes require knowledge of positions of

Algorithm 1 Proposed algorithm outline

-Initialization:
-Transmit sensor location and initial bit distribution to neighboring sensors
-Specify number of protocol rounds/iterations K
-Specify number of clusters C and p_{CH}
FOR $k = 1 : K$
-Select K-CHs
FOR $c = 1 : C$
-CH broadcasts its base selling/bidding price to sensors in its cluster
-Sensors with lower/higher selling/bidding price identify as sellers/buyers and transmit their selling/bidding price to CH.
-CH constructs matching sets for each seller sensor.
-CH deallocates bit from lowest price selling senors and allocates it to highest price bidding sensor.
-Sensors update their thresholds and calculate error
END // C-loop
END // K-loop

sensors that are less than R_s units away which can be performed one time after the initial deployment. Knowledge of the number of bits allocated to each sensor is also required, which can be transmitted by the CH after each algorithm iteration.

1) Estimation error difference: When a sensor wants to determine its selling price, it locally calculates the degradation in estimation performance when one of its bits is removed. Let I_m indicate the set of point indexes within the sensing radius of the m-th sensor. Then the total localization error at these points is given as

$$e(m) = \sum_{i \in I_m^+} \Delta E^L(i) \tag{18}$$

where, I_m^+ denotes indexes of points where requirements are not met and $\Delta E(i)$ is defined as

$$\Delta E(i) = E^L_{\text{res}}(i) - E^L_{\text{req}}(i). \tag{19}$$

When calculating the selling price, the sensor locally calculates the total localization error $e^-(m)$ if one bit was removed. The selling price p_m^- is then defined as

$$p_m^- = |e^-(m) - e(m)| \tag{20}$$

Therefore, as the degradation in anticipated estimation error decreases, the sensor will be more willing to sell its bit. Similarly, the bidding price is then given as

$$p_m^+ = |e^+(m) - e(m)| \tag{21}$$

where, $e^+(m)$ is the error if one bit was added to the sensor. Thus, the larger the improvement in error performance, the greater is the bidding price p_m^+.
The above scheme is not the only scheme that we can propose. We next, propose a pricing scheme that in addition to estimation error, incorporates the number of used bits in calculating a bit's price.

2) Error-Bit Efficiency: In this pricing scheme, we propose to incorporate the error per bit efficiency metric. This enables us to quantify how efficient is the sensor using each of its bits. Let $R(m)$ denote the number of the m-th sensor bits, we define the error-bit efficiency η_m as

$$\eta(m) = \frac{\%e(m)}{R(m)}, \tag{22}$$

where,

$$\%e(m) = \sum_{i \in I_m^+} \frac{E^L_{\text{res}}(i) - E^L_{\text{req}}(i)}{E^L_{\text{req}}(i)} \tag{23}$$

Using the efficiency measure, we can now define the selling/bidding price as

$$p_m^{\pm} = |\eta^{\pm}(m) - \eta(m)| \tag{24}$$

The selling price defined above indicates the relative change in bit efficiency when one bit is to be removed. The smaller the efficiency change, the more willingness to sell the bit and thus the lower price. In case of bidding for bits, sensors with the most efficiency will propose higher bidding prices.

In the next section, we investigate the performance of the proposed protocol.

IV. Simulation Results

To study the performance of our proposed bidding protocol, we use the average error criterion which we define as the difference between achieved and required estimation error requirements over the whole region of interest at the k-th protocol round and is given as

$$\text{Average Error}(l) = \sum_{i \in I_+} \Delta \mathbf{E}^L_k(i),$$

where, I_+ denotes the set of points where error requirements are not satisfied. We also employ the normalized average error criterion which is the overall average error at the k-th iteration normalized with respect to the initial average error before any bidding is performed denoted as Average $\text{Error}_{\text{initial}}$. That is;

$$\text{Normalized Error}(k) = \frac{\text{Average Error}(k)}{\text{Average Error}_{\text{initial}}},$$

We note that we use a number 100 Monte Carlo iteration to average our results over. Another criterion we use is the relative average error gap with respect to the error of that of a solution generated by a 'centralized' genetic algorithm (GA) approach, and is defined as

$$RE_{\text{GA}}(k) = \frac{\text{Average Error}(k) - \text{Average Error}_{\text{GA}}}{\text{Average Error}_{\text{GA}}}$$

where, Average Error_{GA} is the error corresponding to the GA solution. We note that in all of our GA simulations we use a population size of 100 with 30 generations. We also note that the EDQ threshold selection method is used in all of our simulations.

In the first experiment, we investigate the behavior of our proposed protocol for different initial energy P_0 levels for both proposed pricing schemes. We consider a 20×20 ROI, with uniform estimation requirements set to $1.5\ m^2$. Additional experiment parameters as listed in Table. I below (notably,

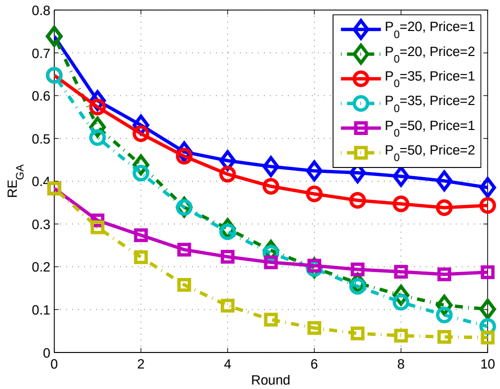


Fig. 1: $RE_{\text{GA}}(k)$ vs. rounds for different P_0. Price=1 and 2 refer to the error difference and error-bit efficiency schemes, respectively.

$M = 30$ sensors with $R_m = 3$ bits for each sensor in addition to using $C = 5$ CHs with $K = 10$ rounds).

b	20
σ^2	1
M	30
N	200
R_s	5
α	0.1
C	5
L	10
R_m	3

TABLE I: Parameters of Experiment Set 1

The relative error gap RE_{GA} is depicted in Fig. 1 below. We first note that the $RE_{\text{GA}}(k)$ decreases as more rounds of the protocol are executed and as P_0 is increased. As P_0 is increased, sensor measurements become more accurate and sensors can more accommodate selling their bits to other sensors. This is especially true for sensors that are within an area of high coverage (i.e., large number of overlapping sensors) where requirements are more satisfied relative to other low coverage areas (i.e., with fewer sensors overlapping) where requirements are less satisfied. More notably, the use of the second pricing scheme (i.e., error-bit efficiency) results in a smaller gap than that of the first pricing scheme (error difference). For example, using the error difference scheme results in an error gap of between $20\% - 38\%$. However, a smaller gap of between $5\% - 10\%$ can be achieved using the second scheme after $K = 10$ rounds. This is a direct result of the incorporation of the relative error difference as well as the number of bits assigned to a sensor.

The second experiment investigates the error performance as we vary the number of cluster heads (C). The experiment parameters are similar to that of the previous experiment with $P_0 = 35$ and a variable C. Results are depicted in Fig. 2 below. We note that increasing C increases the error reduction. This is expected as having more clusters implies more auctions are being performed which results in a faster reduction of errors. However, we note that increasing C has a diminishing return behavior, especially when using the second pricing scheme where increasing C from 3 to 5 results in a small overall improvement in error reduction.

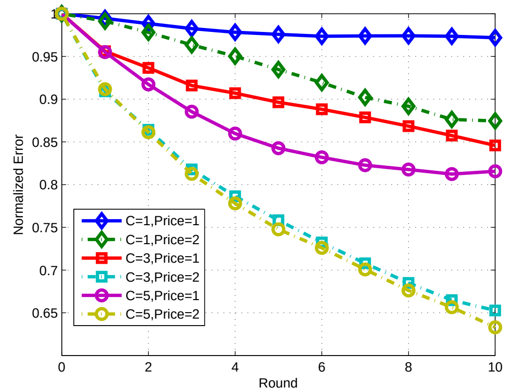


Fig. 2: Normalized error vs. rounds for different C CHs

We next consider a different setup in which sensors are uniformly deployed but with nonuniform bit allocation. In particular, sensors in the upper right corner of the ROI are assigned a number of bits (which we call 'corner bits') different from other sensors which are each assigned one bit ($R_m = 1$). It is evident (see Fig. 3) that the proposed protocol is capable of reducing the average error even when possible bits to be traded are concentrated in one area. We remind the reader that sensors with one bit are prohibited from selling in our protocol. Thus, the more bits are available for exchange, the better the protocol reduces error using any of the pricing schemes. This is especially true fo the error-bit efficiency price which produces a lower selling/bidding price when the number of allocated bits is larger than those of other sensors in cluster. It is noted that this nonuniform bit distribution amplifies the performance difference between the two proposed pricing schemes. An example of the re-distribution of bits among sensors is shown in Figs. 4, 5 that show the initial distribution of bits (with 4 corner bits) as well as that of the GA algorithm's and the proposed protocol pricing schemes.

In the fourth experiment, we consider an ROI with nonuniform estimation requirements as shown in Fig. **??** and parameters as shown in Table. I . From Fig. 7, we note that the more stringent requirements become (i.e., lowering E_{req}), the larger is the error gap with respect to the optimal solution. This is especially true before the protocol is implemented. Satisfying stringent requirements requires moving bits closer to the required region while not degrade performance at other regions. We further note, the as requirements become less stringent (i.e., from $E_{\text{req}} = 0.5$ to $1.5\ m^2$) the larger is the error reduction. That is because estimation errors are more satisfied and thus bits can be traded and moved to areas with more stringent requirements.

Figs. 8 and 9 show an example of the error difference distribution over the ROI, with $E_{\text{req}} = 0.5$ set to the lower left corner. The darker the areas (i.e., lower vale on the color bar) the more the error is satisfied.

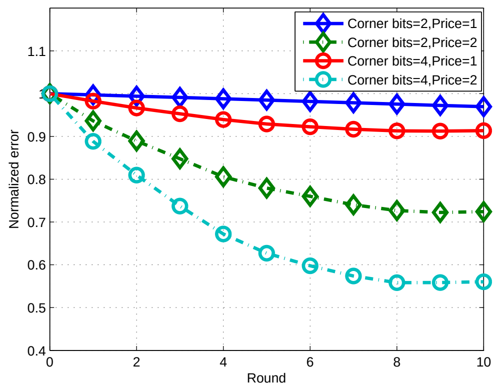
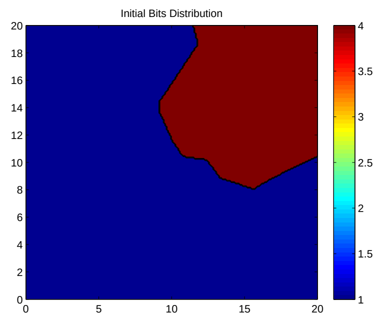
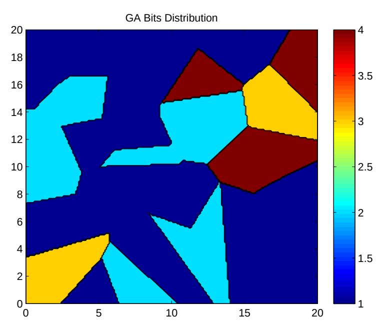


Fig. 3: Normalized error vs. rounds for different bit distributions

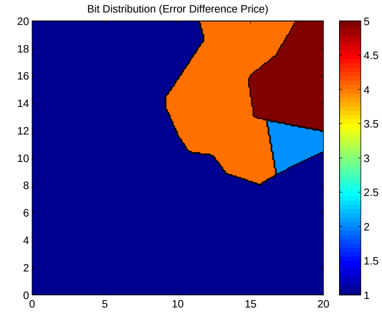


(a) Initial

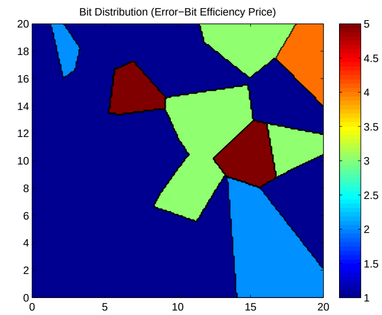


(b) GA

Fig. 4: Initial and GA Bit distribution



(a) Error difference price



(b) Error-Bit efficiency price

Fig. 5: Bit distribution using proposed protocol

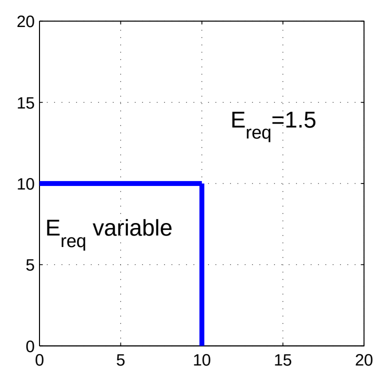


Fig. 6: Nonuniform estimation requirements

V. Conclusion

In this paper, we studied the bit allocation problem for the RSSI-based localization network. Having an initial distribution of sensors, the goal is to re-allocate bits such that estimation requirements at multiple points in the ROI are satisfied as best as possible. To solve this problem, a novel iterative distributed auction/ bidding protocol is introduced. The network is divided into clusters, with each cluster head acting as an auctioneer and dividing sensors into buyers or sellers of bits. Two pricing schemes are proposed; the error difference and error difference-bit efficiency schemes. Simulation results indicate that the proposed protocol can achieve an error performance that is within less than 10% of that a centralized genetic algorithm (GA) approach.

References

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, “Wireless sensor networks: a survey,” *Computer Networks*, vol. 38, no. 4, pp. 393–422, 2002.

[2] J. Yick, B. Mukherjee, and D. Ghosal, “Wireless sensor network survey,” *Computer Networks*, vol. 52, no. 12, pp. 2292–2330, 2008.

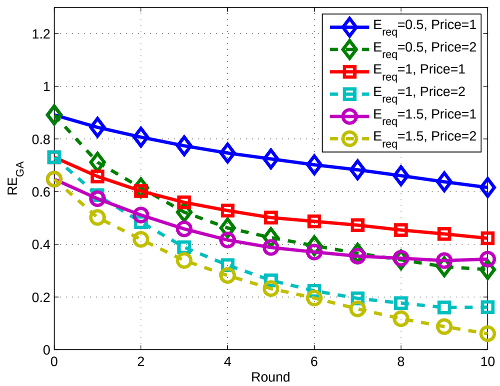
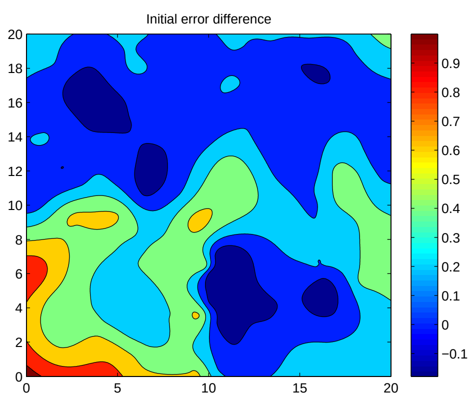
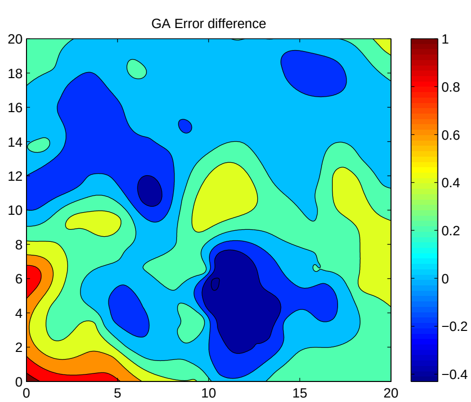


Fig. 7: $RE_{\text{GA}}(k)$ vs. rounds for different requirements

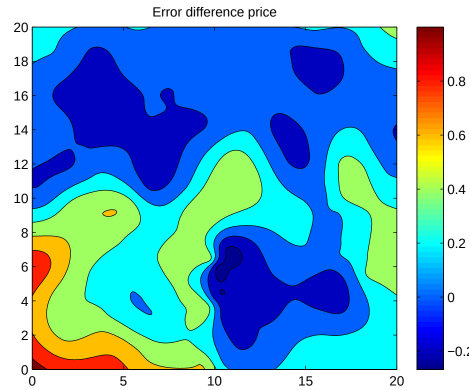


(a) Initial

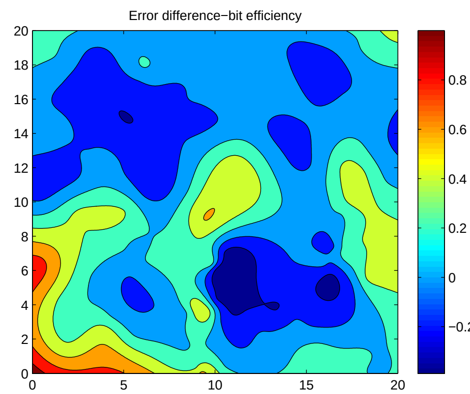


(b) GA

Fig. 8: Initial and GA error difference distribution



(a) Error difference price



(b) Error-Bit efficiency price

Fig. 9: Error distribution using proposed protocol

[3] H. Karl and A. Willig, *Protocols and architectures for wireless sensor networks*. Wiley, 2007.

[4] G. Mao, B. Fidan, G. Mao, and B. Fidan, *Localization Algorithms and Strategies for Wireless Sensor Networks*. Hershey, PA: Information Science Reference - Imprint of: IGI Publishing, 2009.

[5] P. U. Lima, "A bayesian approach to sensor fusion in autonomous sensor and robot networks," *IEEE Instrumentation Measurement Magazine*, vol. 10, no. 3, pp. 22–27, June 2007.

[6] D. Pizarro, M. Mazo, E. Santiso, M. Marron, and I. Fernandez, "Localization and geometric reconstruction of mobile robots using a camera ring," *IEEE Transactions on Instrumentation and Measurement*, vol. 58, no. 8, pp. 2396–2409, Aug 2009.

[7] X. Sheng and Y.-H. Hu, "Maximum likelihood multiple-source localization using acoustic energy measurements with wireless sensor networks," *Signal Processing, IEEE Transactions on*, vol. 53, no. 1, pp. 44–53, 2005.

[8] G. Mao, B. Fidan, and B. Anderson, "Wireless sensor network localization techniques," *Computer Networks*, vol. 51, no. 10, pp. 2529–2553, 2007.

[9] V. K. Chaurasiya, N. Jain, and G. C. Nandi, "A novel distance estimation approach for 3d localization in wireless sensor network using multi dimensional scaling," *Information Fusion*, vol. 15, pp. 5–18, 2014.

[10] A. N. Bishop, B. Fidan, B. D. Anderson, P. N. Pathirana, and K. Dogançay, "Optimality analysis of sensor-target geometries in passive localization: Part 2-time-of-arrival based localization," in *Proceedings of the 3rd International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP)*, 2007.

[11] A. N. Bishop and P. Jensfelt, “An optimality analysis of sensor-target geometries for signal strength based localization,” in *Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP), 2009 5th International Conference on*. IEEE, 2009, pp. 127–132.

[12] A. Gersho and R. M. Gray, *Vector quantization and signal compression*. Springer, 1992.

[13] Y. H. Kim and A. Ortega, “Quantizer design for energy-based source localization in sensor networks,” *Signal Processing, IEEE Transactions on*, vol. 59, no. 11, pp. 5577–5588, Nov 2011.

[14] E. Masazade, R. Niu, and P. Varshney, “Dynamic bandwidth allocation for target tracking in wireless sensor networks,” in *Information Fusion (FUSION), 2011 Proceedings of the 14th International Conference on*, July 2011, pp. 1–8.

[15] ——, “Dynamic bit allocation for object tracking in wireless sensor networks,” *Signal Processing, IEEE Transactions on*, vol. 60, no. 10, pp. 5048–5063, Oct 2012.

[16] A. Ababneh, L. Akter, and F. Zghoul, “Quantizer design for RSSI-based target localization in sensor networks.”

[17] Y. Zhang, C. Lee, D. Niyato, and P. Wang, “Auction approaches for resource allocation in wireless systems: A survey,” *IEEE Communications Surveys Tutorials*, vol. 15, no. 3, pp. 1020–1041, Third 2013.

[18] S. Sengupta and M. Chatterjee, “Designing auction mechanisms for dynamic spectrum access,” *Mobile Networks and Applications*, vol. 13, no. 5, pp. 498–515, 2008.

[19] J. Sun, E. Modiano, and L. Zheng, “Wireless channel allocation using an auction algorithm,” *Selected Areas in Communications, IEEE Journal on*, vol. 24, no. 5, p. 1085, 2006.

[20] J. Bae, E. Beigman, R. A. Berry, M. L. Honig, and R. Vohra, “Sequential bandwidth and power auctions for distributed spectrum sharing,” *Selected Areas in Communications, IEEE Journal on*, vol. 26, no. 7, pp. 1193–1203, 2008.

[21] G. Wang, G. Cao, and T. LaPorta, “A bidding protocol for deploying mobile sensors,” in *Network Protocols, 2003. Proceedings. 11th IEEE International Conference on*. IEEE, 2003, pp. 315–324.

[22] E. Elnahrawy, X. Li, and R. P. Martin, “The limits of localization using signal strength: A comparative study,” in *Sensor and Ad Hoc Communications and Networks, 2004. IEEE SECON 2004. 2004 First Annual IEEE Communications Society Conference on*. IEEE, 2004, pp. 406–414.

[23] F. Gustafsson, F. Gunnarsson, and D. Lindgren, “Sensor models and localization algorithms for sensor networks based on received signal strength,” *EURASIP Journal on Wireless Communications and Networking*, vol. 2012, no. 1, pp. 1–13, 2012.

[24] R. Niu and P. Varshney, “Target location estimation in sensor networks with quantized data,” *Signal Processing, IEEE Transactions on*, vol. 54, no. 12, pp. 4519–4528, 2006.

[25] O. Ozdemir, R. Niu, and P. Varshney, “Channel aware target localization with quantized data in wireless sensor networks,” *Signal Processing, IEEE Transactions on*, vol. 57, no. 3, pp. 1190–1202, 2009.

[26] H. V. Poor, *An introduction to signal detection and estimation*. Springer-Verlag, 1988.

[27] B. C. Levy, *Principles of signal detection and parameter estimation*. Springer, 2008.

[28] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, “Energy-efficient communication protocol for wireless microsensor networks,” in *System Sciences, 2000. Proceedings of the 33rd Annual Hawaii International Conference on*, Jan 2000, pp. 10 pp. vol.2–.

[29] A. A. Abbasi and M. Younis, “A survey on clustering algorithms for wireless sensor networks,” *Computer Communications*, vol. 30, no. 14, pp. 2826–2841, 2007.

[30] P. Saini and A. K. Sharma, “E-DEEC- enhanced distributed energy efficient clustering scheme for heterogeneous wsn,” in *Parallel Distributed and Grid Computing (PDGC), 2010 1st International Conference on*, Oct 2010, pp. 205–210.

An Extension of the Bisection Theorem to Symmetrical Circuits with Cross-Coupling

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***Abstract*—This paper demonstrates that the bisection theorem can be applied to the differential and common-mode analysis of balanced symmetrical circuits with cross coupling. This class of circuits is often found in the literature. The application of the circuit greatly reduces the complexity of the circuit thereby greatly simplifying the analysis and providing insight.**

***Index Terms*—Bisection theorem; common-mode analysis; cross-coupling; differential amplifiers; differential-mode analysis.**

I. Introduction

The bisection theorem (sometimes referred to as Bartletts bisection theorem) is a powerful tool that can be used to analyze balanced symmetrical circuits with two inputs. A balanced symmetrical circuit is a circuit that can be topologically divided into two identical parts, identical in both topology and component and variable values. The two inputs are often decomposed into differential and common-mode inputs and then the differential-mode and common-mode responses can be determined independently. The main advantage of applying the bisection theorem is in reducing the circuit for the differential and common-mode analysis to one half of the entire circuit. The resulting circuits are often term differential-mode and common-mode half-circuits. In both, the results of the analysis of a half-circuit and be applied to the other half-circuit to complete the analysis, if necessary.

The idea behind the theory was first introduced by Bartlett[1]. After that the bisection theorem was discussed by Brune [2] and Iyer [3] where geometrically symmetrical circuits where treated . In 1941 Cauer published the first volume of his main work on circuit theory titled Theorie der linearen Wechselstromschaltungen. Leipzig and later on,in 1958, he had an extended edition Synthesis of Linear Communication Networks, McGraw-Hill, New York, 1958 where he discussed Barletts and Bruness theorem. In Cauers work an extension to symmetric 4-ports was presented. And Cauer was able to extend the theorem to electrically symmetrical circuits where the response of each half is symmetrical and the physical implementation of the circuit is not required [4].

The bisection theorem has been applied to the analysis of balanced, symmetrical circuits and in particular to differential amplifiers [5], [6], [7]. Barletts theorem gives parallel and series impedance when only there is direct connection between the two halves [8]. Matheau was able to prove that even if the two-terminal-pair network exhibits only vertical symmetry, it is always possible to find the parallel impedance Zj, of the equivalent symmetrical lattice. Matheau assumed that the current in both halves are equal [8].

There are many examples of circuits that are similar to balanced symmetrical circuits except cross-coupling exists between two halves thereby making them ineligible for application of the bisection theorem because each half has a dependency found in the other half. Although there are some end results in the form of equations and figures, the reasoning and means to those ends have never been discussed [9], [10], [11], [12] or has the Bisection theorem been applied or discussed. Moreover, the common-mode analysis of these circuits has never been performed. The purpose of this paper is to show that the bisection theorem can be extended so that it may be applied to a wider class of circuits than balanced symmetrical circuits, that is, it can be applied to a class of circuits called balanced symmetrical circuits with identical cross-coupling. This class of circuit is often found in the literature.

Sect.II of this paper reviews the bisection theorem. In Sect.III, it is shown that for both the differential-mode and common analysis, the balanced symmetrical circuits with identical cross-coupling can be transformed to and equivalent balanced symmetrical circuit and then the bisection theorem can be applied. In Sect.IV, examples are shown.

II. The Bisection Theorem

In this section, a review of the development of the bisection theorem is presented. This review follows the development presented by Brune and Iyer [3].

Consider a symmetrical circuit depicted by Fig.1. A circuit is symmetrical if it can be topologically divided into two mirror-image parts. Only the case where a direct connection between the two halves exists is considered. In Fig.1, the input signals can be decomposed into their differential-mode and common-mode components. That is

$$\begin{aligned} V_{in1} &= V_{icm} + \frac{V_{id}}{2} \\ V_{in2} &= V_{icm} - \frac{V_{id}}{2} \end{aligned} \tag{1}$$

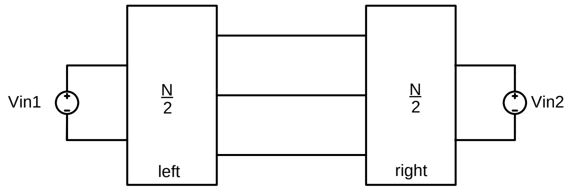

Fig. 1: A depiction of a balanced symmetrical circuit.

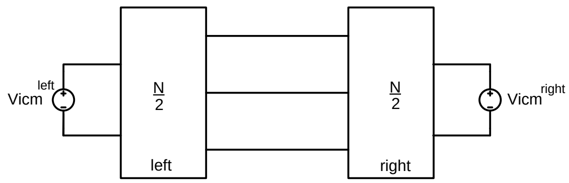

Fig. 2: A schematic depicting the case where the common-mode response is desired.

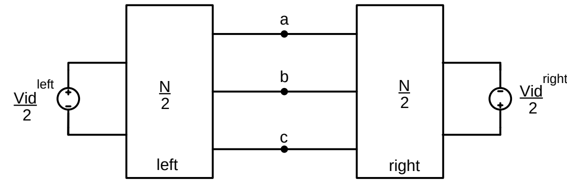

Fig. 4: A schematic depicting the case where the differential-mode response is desired.

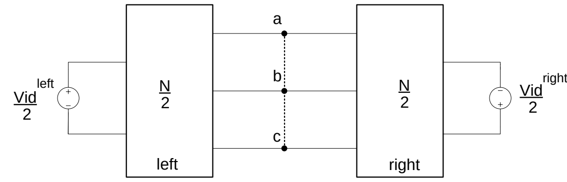

Fig. 5: Differential-mode circuit bisected into two equivalent, independent halves.

Fig.2 depicts the case where only the common-mode response is desired. $V_{id} = 0$ and $V_{in1} = V_{icm} = V_{in2}$. To determine the common-mode response, superposition may be applied and the analysis is done in two steps: (i) $V_{icm}^{right} = 0$ and the response to V_{icm}^{left} is determined, (ii) $V_{icm}^{left} = 0$ and the response to V_{icm}^{right} is determined.

In step (i) current flows from the left half to the right half through each of the connecting wires. In step (ii) current flows from right half to the left half. This current is equal in magnitude and 180 degrees out of phase with the previous step. Thus, the total current that flows between the two halves is in each of the wires is 0.

Based on the results of the previous analysis, the circuit in Fig.2 can be transformed to an equivalent circuit shown in Fig.3. For this case, the halves are bisected along the vertical defined by $x - y$ and the connections between the two halves are opened, decomposing the circuit into two equivalent, independent circuits. There is a significant reduction in complexity since only one half the circuit needs to be analyzed, with the results of the analysis now applicable to the second half.

Next, the case where the differential-mode response is considered. For this case,$V_{icm} = 0$ and $V_{in1} = \frac{V_{id}}{2} = -V_{in2}$. This case is depicted in Fig.4.

Superposition is applied the schematic in Fig.4 to determine

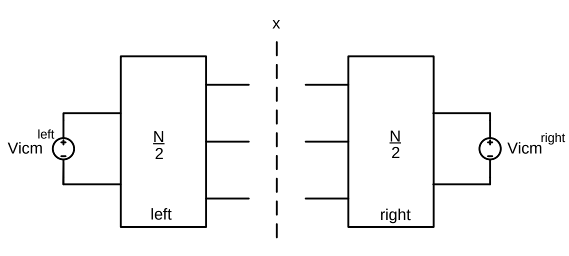

Fig. 3: Common-mode circuit bisected into two equivalent, independent halves.

the differential-mode response in two steps: (i) $\frac{V_{id}^{right}}{2} = 0$ and the response to $\frac{V_{id}^{left}}{2}$ is determined, (ii) $\frac{V_{id}^{left}}{2} = 0$ and the response to $\frac{V_{id}^{right}}{2}$ is determined.

In case (i), V_{ab}^{left}, V_{bc}^{left}, and V_{ac}^{left} are determined. In case (ii), the source sees the same circuit as the source in case (i). Since the sources are equal in magnitude, but 180 degrees $V_{ab}^{right} = -V_{ab}^{left}$, $V_{bc}^{right} = -V_{bc}^{left}$, $V_{ac}^{right} = -V_{ac}^{left}$. Thus, $V_{ab} = V_{ab}^{right} + V_{ab}^{left} = 0$. Likewise, $V_{bc} = V_{cb} = 0$ and in summary, and any branch voltage that can be defined based on any pairing of wires is zero. Thus, all of the connecting wires can be treated as though they are bound by a virtual short circuit. This can be extended to the case of "n"branches, that will result in $\sum_{i=1}^{n-1} n - i$ wire pairings and so all branch voltages are zero. In practice, one of the connecting wires is often at ground, resulting in all node voltages defined with reference to ground. Thus, the voltages at the connecting wires are at zero and be treated as a virtual ground.

Based on the results of the previous the circuit can be transformed to the equivalent circuit of Fig.5. For this case the halves are bisected and the connections between the two halves are connected with a dotted line that symbolizes a virtual short. As with the common-mode analysis, there is an enormous reduction in complexity since only one half the circuit needs to be analyzed, with the results of the analysis now applicable to the second half by setting all voltages and currents 180 degrees out of phase with the counterpart halve.

III. Extension of the Bisection Theorem

To extend the bisection theorem to the case where cross-coupling exists, it is first shown that this case can be transformed into a symmetrical circuit with two identical halves for both the common-mode and differential-mode cases. Once the transformations have been made, the results of Sect.III can be applied. For convenience, a two-port network described using Y-parameters models each individual cross-coupling circuit in the set. For each individual cross-coupling circuit, one

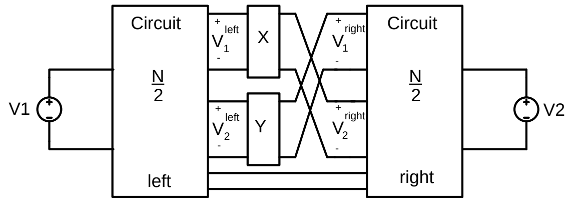

Fig. 6: A depiction of a circuit where two identical sections are connected by a set of cross-coupling circuits and by wires.

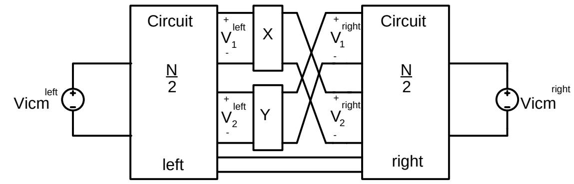

Fig. 7: A schematic depicting a cross-coupled circuit for the case where the common-mode response is desired.

independent voltage resides in one section and the second independent voltage resides in the other section

Consider the schematic show in Fig.6 for the case where two identical sections that are mirror images of each other exist and each section has identical cross-coupling from the other. Cross-coupling is taken to mean that the section on the left has a dependency on the section on the right via a cross-coupling circuit and vice versa.

Since the topology of each section is identical, every branch voltage in the left-hand sign has a counterpart branch voltage in the right-hand side. For example, if a branch voltage is defined across a single resistor in the left section, that resistor has a mirror image in the right section and there is a branch voltage across that resistor that corresponds to the voltage across the resistor in the left section. In general, if V_i^{left} exists in the left hand side, there is a counterpart V_i^{right} in the right hand side.

For convenience, the cross-coupling circuits are modelled with Y-parameters. The general set of equations that models the cross-coupling circuits is:

$$\begin{aligned} I_1 &= Y_{11} \cdot V_1 + Y_{12} \cdot V_2 \\ I_2 &= Y_{21} \cdot V_1 + Y_{22} \cdot V_2 \end{aligned} \tag{2}$$

For each cross-coupled circuit, the branch voltage V_1 is found in one symmetrical halve original and the branch voltage V_2 is found in other. Thus, port relationships for the cross coupling circuit labeled “X”can be expressed as:

$$\begin{aligned} I_1 &= Y_{11} \cdot V_1^{left} + Y_{12} \cdot V_2^{right} \\ I_2 &= Y_{21} \cdot V_1^{left} + Y_{22} \cdot V_2^{right} \end{aligned} \tag{3}$$

The port relationships for the cross-coupling circuit labelled “Y”can be expressed as:

$$\begin{aligned} I_1 &= Y_{11} \cdot V_1^{right} + Y_{12} \cdot V_2^{left} \\ I_2 &= Y_{21} \cdot V_1^{right} + Y_{22} \cdot V_2^{left} \end{aligned} \tag{4}$$

Fig.7 depicts the schematic used for the common-mode analysis. Superposition is applied to determine the response in two steps: (i) $V_{icm}^{right} = 0$ and the response to V_{icm}^{left} is determined, (ii) $V_{icm}^{left} = 0$ and the response to V_{icm}^{right} is determined.

V_1 will be considered first. In step (i), $V_1^{left,i}$ and $V_1^{right,i}$ are determined. In step (ii), $V_1^{left,ii}$ and $V_1^{right,ii}$ because both sources see identical circuits $V_1^{left,i} = V_1^{right,ii}$ and $V_1^{right,i} = V_1^{left,ii}$. Thus, $V_1^{left} = V_1^{left,i} + V_1^{left,ii} = V_1^{ritht,ii} + V_1^{right,i} = V_1^{right}$. Thus V_1^{left} is equal to its counterpart voltage V_1^{right}. Likewise, V_2^{left} is equal to its counterpart voltage V_2^{right} and in general, all counterpart voltages and currents are equal. This means for the case of a common-mode input voltage that the two-ports can be described with the Eqs. (5) and (6).

$$\begin{aligned} I_1 &= Y_{11} \cdot V_1^{left} + Y_{12} \cdot V_2^{left} \\ I_2 &= Y_{21} \cdot V_1^{left} + Y_{22} \cdot V_2^{left} \end{aligned} \tag{5}$$

$$\begin{aligned} I_1 &= Y_{11} \cdot V_1^{right} + Y_{12} \cdot V_2^{right} \\ I_2 &= Y_{21} \cdot V_1^{right} + Y_{22} \cdot V_2^{right} \end{aligned} \tag{6}$$

The dependencies for each cross coupling circuit have been moved to a single half. The circuit now meets the criteria for a symmetrical circuit and the analysis shown in Sect.II can be applied. For practical circuits, the movement from Eqs. (3) and (4) to Eqs. (5) and (6) can be achieved by performing operations on the schematic that effectively achieve the same end.

Fig.8 depicts the schematic for the case where the differential-mode analysis. Superposition is applied to determine the response in two steps: (i) $\frac{V_{id}^{right}}{2} = 0$ and the response to $\frac{V_{id}^{left}}{2}$ is determined, (ii) $\frac{V_{id}^{left}}{2} = 0$ and the response to $\frac{V_{id}^{right}}{2}$ is determined.

V_1 will be considered first. In step (i), $V_1^{left,i}$ and $V_1^{right,i}$ are determined. In step (ii), $V_1^{left,ii}$ and $V_1^{right,ii}$ because both sources see identical circuits $V_1^{left,i} = -V_1^{right,ii}$ and $V_1^{right,i} = -V_1^{left,ii}$. Thus, $V_1^{left} = V_1^{left,i} + V_1^{left,ii} = -V_1^{ritht,ii} + -V_1^{right,i} = -V_1^{right}$. Thus $\frac{left}{V1}$ is equal in magnitude but opposite in phase to its counterpart voltage V_1^{right}. Likewise, V_2^{left} is equal in magnitude but opposite in phase to its counterpart voltage to its counterpart voltage V_2^{right} and in general, all counterpart voltages and currents are equal in magnitude and opposite in phase. This means for the case of a differential-mode input voltage that the two-ports can be described with the Eqs. (7) and (8).

$$\begin{aligned} I_1 &= Y_{11} \cdot V_1^{left} - Y_{12} \cdot V_2^{left} \\ I_2 &= Y_{21} \cdot V_1^{left} - Y_{22} \cdot V_2^{left} \end{aligned} \tag{7}$$

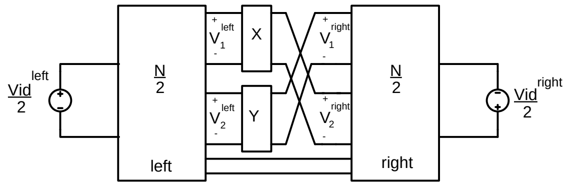

Fig. 8: A schematic depicting a cross-coupled circuit for the case where the differential-mode response is desired.

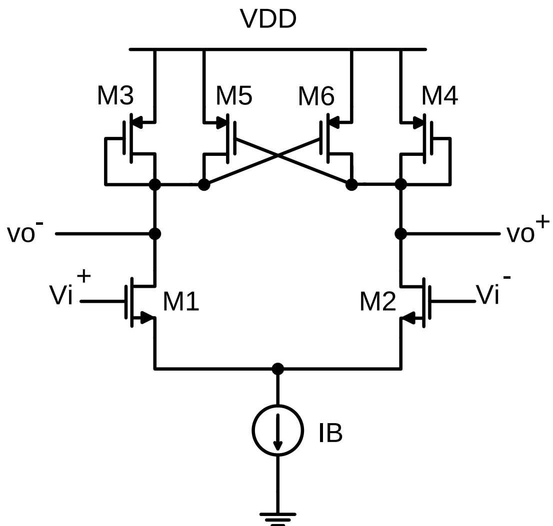

Fig. 9: A differential amplifier with cross-coupling.

$$
\begin{aligned}
I_1 &= Y_{11} \cdot V_1^{right} - Y_{12} \cdot V_2^{right} \\
I_2 &= Y_{21} \cdot V_1^{right} - Y_{22} \cdot V_2^{right}
\end{aligned} \tag{8}
$$

The circuit now meets the criteria for a symmetrical circuit and the analysis shown in Sect. II can be applied. For practical circuits, the movement from Eqs. (3) and (4) to Eqs. (7) and (8) can be achieved by performing operations on the schematic that effectively achieve the same end.

The results of this are easily extended to the case of where the cross-coupling circuit can be modelled with an n-port and for the case where multiple sets of cross-coupling exist. The purpose of this section was to demonstrate that for any conceivable number of cross-couplings circuits with any conceivable number of ports, that the Bisection theorem can be applied by first transforming the differential and common-mode circuits to meet the criteria of the Bisection theorem. In practice, the circuits are much simpler.

IV. Examples

An example of a circuit with cross-coupling is provided in Fig.9 [10]. In this schematic M_1 and M_3 form one section and M_2 and M_4 form a mirror image. M_5 forms one cross-coupling circuit and M_6 forms the other.

An AC equivalent circuit is shown in Fig.10. The output resistance of the current source has been split into two resistors

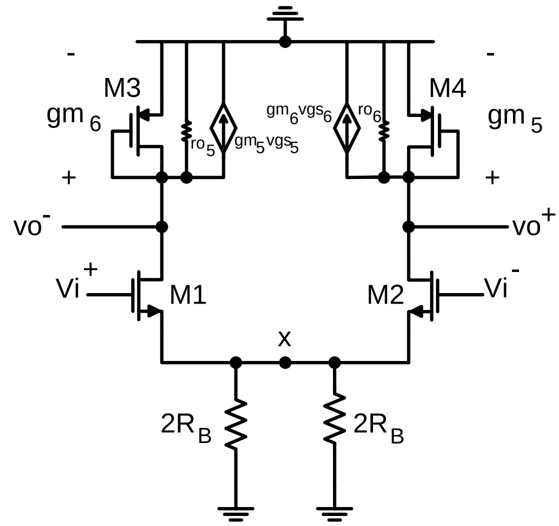

Fig. 10: AC schematic for the differential pair with cross-coupling.

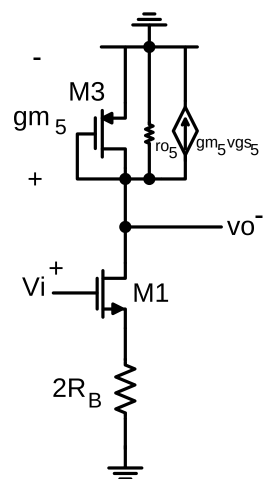

Fig. 11: An AC equivalent for a common-mode half-circuit

so that bisection at node "x"can be performed. M_5 and M_6 are replaced with small-signal models.

The ideal common-mode gain when the output is taken differentially is zero. However, it has been shown that when there is mismatch the common-mode gain is no longer zero and a common-mode half circuit can still provide useful qualitative and quantitative information about the common-mode response [13]. For the common-mode response, $V_i^+ = V_{icm} = V_i^-$. The connecting wire at 'x'can be cut and opened. V_{gs5} has a counterpart voltage V_{gs6} and so they are equal. The dependency of M_5 is moved to the left half and the dependency of M_6 is moved to the right half. The circuit can now be bisected. A resulting AC schematic for a half-circuit is shown in Fig.11.

The voltage controlled current source can be replaced with a

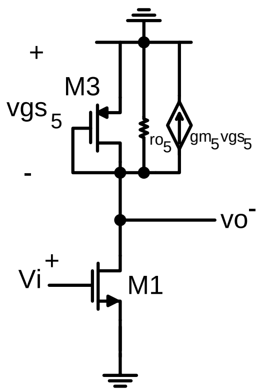

Fig. 12: An AC equivalent for a differential-mode half-circuit

resistor with a value of $\frac{1}{gm5}$. The common-mode half-circuit forms a common-source amplifier with source degeneration. The drain resistance of M_1 is significantly reduced by M_5 due to the cross coupling. The expression for the drain resistance of M_5 is:

$$R_D = \left(\frac{1}{gm_3}\|r_{o3}\|\frac{1}{gm_5}\|r_{o5}\right) \tag{9}$$

The single-ended common-mode gain is expressed as:

$$A_{cm,se} = \frac{-gm_1 \cdot R_D}{1 + 2 \cdot \left(gm_1 + gmb_1 + \frac{1}{r_{o1}}\right) \cdot R_B + \frac{R_D}{r_{o1}}} \tag{10}$$

Equation (10) can be simplified to:

$$A_{cm,se} = \frac{1}{2 \cdot (gm_3 + gm_5) \cdot R_B} \tag{11}$$

For the differential-mode response, $V_i^+ = \frac{V_{id}}{2} = -V_i^-$. The connecting wire between the R_B can set to zero. V_{gs5} has a counterpart voltage Vgs6 so they are in magnitude but opposite in phase and so $V_{gs5} = -V_{gs6}$. The dependency of M_5 is moved to the left half and the dependency of M_6 is moved to the right half. The circuit can now be bisected. A resulting AC schematic for a half-circuit is shown in Fig.12.

The voltage controlled current source can be replaced with resistors with a value $\frac{-1}{gm_5}$. The differential-mode half-circuit forms a common-source amplifier The drain resistance of M_1 can be made significantly larger since the overall drain resistance can be increased significantly due to the cross-coupling transistor M_5 acting as a negative resistance. The differential-mode gain for the single-ended out is:

$$A_{dm,se} = -\frac{1}{2}gm_1 \cdot \left(\frac{1}{gm_3}\|r_{o3}\|\frac{1}{gm_5}\|r_{o5}\right) \tag{12}$$

The differential-mode gain for the differential output is:

$$A_{dm,do} = gm_1 \cdot \left(\frac{1}{gm_3}\|r_{o3}\|\frac{1}{gm_5}\|r_{o5}\right) \tag{13}$$

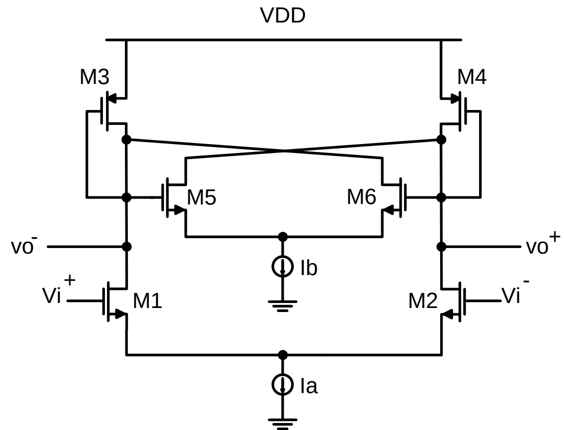

Fig. 13: A schematic of a differential amplifier where the cross-coupling is achieved with a second differential pair.

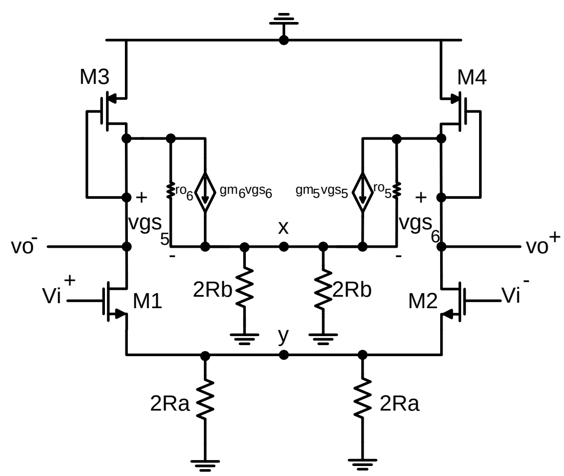

Fig. 14: An AC schematic of a differential amplifier where the cross-coupling is achieved with a second differential pair.

An example of a more complicated circuit with cross-coupling is shown in Fig.13 [14]. The AC equivalent circuit is shown in Fig.14.

The output resistance of Ia and Ib have been represented by two resistances rather than one in order to bisect the circuits. Fig.14 does not fit the case depicted by Fig.6 since there are not two identical cross-coupled circuits, but a single cross-coupling circuit formed by a differential pair.

For the common-mode analysis, the schematic in Fig.14 can be transformed to a half-circuit by cutting the connecting wire at 'x'and 'y'and opening both by the line of reasoning found in Sect.II V_{gs5} has a counterpart voltage V_{gs6} and so they are equal. The dependency of M_5 is moved to the left half and the dependency of M_6 is moved to the right half. The circuit has now been can now be bisected. A resulting AC schematic for a half-circuit is shown in Fig.15. The result is a common-source amplifier with source degeneration.

The drain resistance for M_1 is M_3 which is diode connected

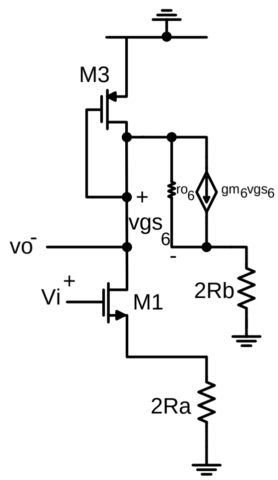

Fig. 15: An AC equivalent for a common-mode half-circuit.

in parallel with the resistance looking into the drain of M_6, which behaves like a cascode. Thus, the drain resistance of M_1 is approximately:

$$R_D \approx \frac{1}{gm_3} \tag{14}$$

The single-ended common mode gain is expressed is:

$$A_{cm,se} = \frac{-gm_1 \cdot R_D}{1 + 2 \cdot \left(gm_1 + gmb_1\right) \cdot R_a + \dfrac{R_D}{r_{o1}}} \tag{15}$$

This can be simplified to:

$$A_{cm,se} = -\frac{1}{2 \cdot gm_1 \cdot R_a} \tag{16}$$

For the differential-mode analysis, the schematic in Fig.14 can be transformed to a half-circuit by cutting the connecting shorting the connecting wires at ‘x’and ‘y’by the line of reasoning found in Sect.II. V_{gs5} has a counterpart voltage V_{gs6} so they are in magnitude but opposite in phase and so $V_{gs5} = -V_{gs6}$. The dependency of M_5 is moved to the left half and the dependency of $M6$ is moved to the right half. The circuit is now be bisected. A resulting AC schematic for a half-circuit is shown in Fig.16.

The circuit in Fig.16 is topologically identically to that in Fig.12 so those results apply for this case. The differential-mode gain for the single-ended out is:

$$A_{dm,se} = -\frac{1}{2} gm_1 \cdot \left(\frac{1}{gm_3} \| r_{o3} \| \frac{1}{gm_5} \| r_{o5}\right) \tag{17}$$

The differential-mode gain for the differential output is:

$$A_{dm,do} = gm_1 \cdot \left(\frac{1}{gm_3} \| r_{o3} \| \frac{1}{gm_5} \| r_{o5}\right) \tag{18}$$

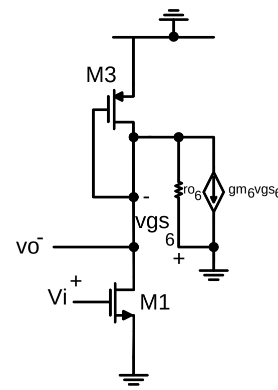

Fig. 16: An AC equivalent for a differential-mode half-circuit

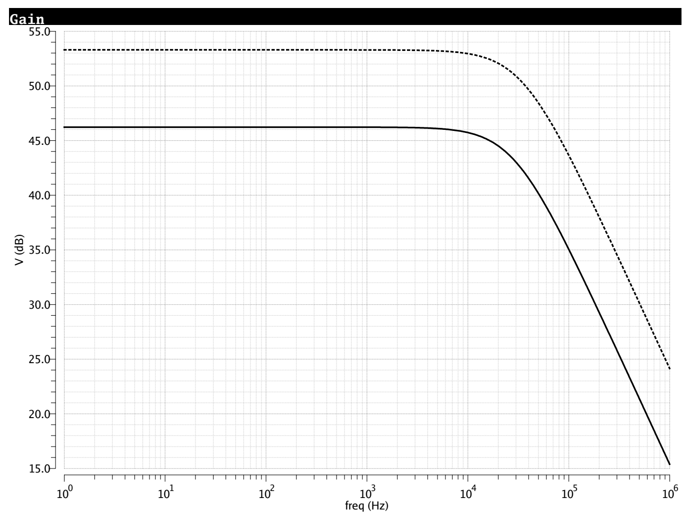

Fig. 17: Gain simulation for the differential amplifier with cross coupling where $W_1 = 10\mu m$ and $W_2 = 10\mu m$ in solid line and $W_1 = 100\mu m$ and $W_2 = 100\mu m$ in dot line

V. Simulation Results

Both examples shown in IV are simulated using cadence simulation tools in order to verify the equations developed for both circuits. Going back to Eq. 13, it can be seen that when gm_1 and gm_2 are increased, the gain of the differential amplifier with cross coupling shown in Fig. 9 is accordingly increased as shown in Fig.17. gm_1 and gm_2 can be increase by increasing W_1 and W_2 or by increasing the tail current. W_1 and W_2 are set to be equal to $10\mu m$ where the gain for low frequencies is equal to $46dB$ as shown in solid line in Fig.17 and when W_1 and W_2 are set to be equal to $100\mu m$, the gain for low frequencies is equal to $53.2dB$ as shown in dots line in Fig.17.

Similarly, going back to Eq. 18, it can be seen that when gm_1 and gm_2 are increased, the gain of the circuit shown in Fig. 13 is accordingly increased as shown in Fig.18. gm_1 and gm_2 can be increase by increasing W_1 and W_2 or by increasing the tail current. W_1 and W_2 are set to be equal to

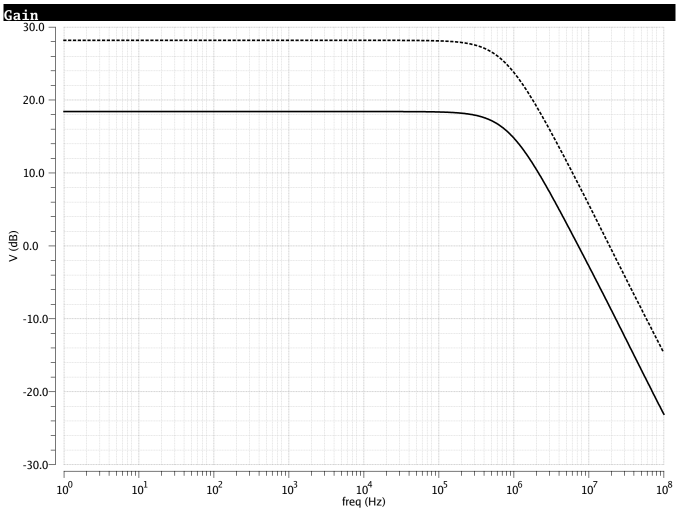

Fig. 18: Gain simulation for the differential amplifier where the cross-coupling is achieved with a second differential pair. $W_1 = 10\mu m$ and $W_2 = 10\mu m$ in solid line and $W_1 = 100\mu m$ and $W_2 = 100\mu m$ in dot line

$10\mu m$ where the gain for low frequencies is equal to $18.2dB$ as shown in solid line in Fig.17 and when W_1 and W_2 are set to be equal to $100\mu m$, the gain for low frequencies is equal to $28dB$ as shown in dots line in Fig.18.

VI. SUMMARY

It has been shown that the Bisection theorem can be extended to include to the case of a balanced circuit with cross-coupling for any number of cross-coupling sets and any level of complexity as long as each set of cross-coupling circuits contains individual cross-coupling circuits that are equal. The results of the extension have been applied to two differential amplifiers with cross-coupling that are currently found in the literature to do a differential and common-mode analysis. The method made clear the steps in determining the half-circuits and provided insight while reducing complexity of the analysis.

REFERENCES

[1] A. C. Bartlett, *The theory of electrical artificial lines and filters*. Wiley, 1930.

[2] O. Brune, "Note on bartlett's bisection theorem for 4-terminal electrical networks," *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, vol. 14, no. 93, pp. 806–811, 1932.

[3] T. Iyer, *Circuit theory*. Tata McGraw-Hill Education, 1985.

[4] V. Belevitch, "Summary of the history of circuit theory," *Proceedings of the IRE*, vol. 50, no. 5, pp. 848–855, 1962.

[5] R. D. Middlebrook, "Differential amplifiers," 1963.

[6] P. R. Gray, P. J. Hurst, R. G. Meyer, and S. H. Lewis, *Analysis and design of analog integrated circuits*. John Wiley & Sons, 2008.

[7] L. J. Giacoletto, "Differential amplifiers," 1970.

[8] J. Matheau, "Two-terminal-pair network bisection," *Electronics Letters*, vol. 1, no. 5, pp. 131–131, 1965.

[9] B. Nauta, "A cmos transconductance-c filter technique for very high frequencies," *Solid-State Circuits, IEEE Journal of*, vol. 27, no. 2, pp. 142–153, 1992.

[10] M. M. Amourah and R. L. Geiger, "A high gain strategy with positive-feedback gain enhancement technique," in *Circuits and Systems, 2001. ISCAS 2001. The 2001 IEEE International Symposium on*, vol. 1. IEEE, 2001, pp. 631–634.

[11] D.-L. Shen and W.-T. Lee, "A negative resistance compensated switching current sampled-and-hold circuit," in *Circuits and Systems and TAISA Conference, 2009. NEWCAS-TAISA'09. Joint IEEE North-East Workshop on*. IEEE, 2009, pp. 1–4.

[12] G. Pei and E.-C. Kan, "Independently driven dg mosfets for mixed-signal circuits: part ii-applications on cross-coupled feedback and harmonics generation," *Electron Devices, IEEE Transactions on*, vol. 51, no. 12, pp. 2094–2101, 2004.

[13] B. Razavi, *Dsign Of Analog CMOS Intgrtd Circuits*, ser. McGraw-Hill series in electrical and computer engineering: Circuits and systems. Tata McGraw-Hill, 2002.

[14] R. Wang and R. Harjani, "Partial positive feedback for gain enhancement of low-power cmos otas," *Analog Integrated Circuits and Signal Processing*, vol. 8, no. 1, pp. 21–35, 1995.

Data Mining in Education

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***Abstract*—Data mining techniques are used to extract useful knowledge from raw data. The extracted knowledge is valuable and significantly affects the decision maker. Educational data mining (EDM) is a method for extracting useful information that could potentially affect an organization. The increase of technology use in educational systems has led to the storage of large amounts of student data, which makes it important to use EDM to improve teaching and learning processes. EDM is useful in many different areas including identifying at-risk students, identifying priority learning needs for different groups of students, increasing graduation rates, effectively assessing institutional performance, maximizing campus resources, and optimizing subject curriculum renewal. This paper surveys the relevant studies in the EDM field and includes the data and methodologies used in those studies.**

***Index Terms*—Data mining, Educational Data Mining (EDM), Knowledge extraction.**

I. Introduction

One of the primary goals of any educational system is to equip students with the knowledge and skills needed to transition into successful careers within a specified period. How effectively global educational systems meet this goal is a major determinant of both economic and social progress.

Some countries provide free education for all citizens from grade one through the university years. Therefore, a large number of students enter universities every year. For example, King Khalid University (KKU) accepted approximately 23,000 students in 2013. It has become difficult to provide high quality teaching and guidance to such a large number of students. As a result, many students fail to complete their degrees within the required periods. EDM can present universities with a clear picture of specific hindrances to student learning. For example, students can fail in advanced subjects because they did not learn the basic information from the prerequisite subjects. Using data mining (DM) techniques to analyze student information can help identify possible reasons for student failures.

Data mining provides many techniques for data analysis. The large amount of data currently in student databases exceeds the human ability to analyze and extract the most useful information without help from automated analysis techniques. Knowledge discovery (KD) is the process of nontrivial extraction of implicit, unknown, and potentially useful information from a large database. Data mining has been used in KD to discover patterns with respect to a users needs. The pattern definition is an expression in language that describes a subset of data. An example of a KD pattern definition appears in [1].

The increasing use of technology in educational systems has made a large amount of data available. EDM provides a significant amount of relevant information [2] and offers a clearer picture of learners and their learning processes. It uses DM techniques to analyze educational data and solve educational issues. Similar to other DM techniques extraction processes, EDM extracts interesting, interpretable, useful, and novel information from educational data. However, EDM is specifically aimed at developing methods that use unique types of data in educational systems [3]. Such methods are then used to enhance knowledge about educational phenomena, students, and the settings in which they learn [4]. Developing computational approaches that combine data and theory will help improve the quality of T& L processes.

From a practical point of view, EDM allows users to extract knowledge from student data. This knowledge can be used in different ways such as to validate and evaluate an educational system, improve the quality of T& L processes, and lay the groundwork for a more effective learning process [5]. Similar ideas have been applied successfully, especially in business data, in different datasets, such as e-commerce systems, to increase sales profits [6]. Thus, the success of applying DM techniques in business data encourages its adoption in different domains of knowledge. Notably, DM has been applied to educational data for research objectives such as improving the learning process and guiding students learning or acquiring a deeper understanding of educational phenomena. However, while EDM has made comparatively less progress in this direction than other fields, this situation is changing due to increased interest in the use of DM in the educational environment [7].

Many tasks or problems in educational environments have been managed or resolved through EDM. Baker [8], [4] suggested four key areas of EDM application: improving student models, improving domain models, studying the pedagogical support provided by learning software, and conducting scientific research on learning and learners. Five approaches/methods are available: prediction, clustering, relationship mining, distillation of data for human judgment, and discovery with models. Castro [9] categorized EDM tasks into four different areas: applications that deal with the assessment of students learning performance, course adaptation and learning recommendations to customize students learning based on individual students behaviors, developing a method to evaluate materials in online courses, approaches that use feedback from students and teachers in e-learning courses, and detection models for uncovering student learning behaviors.

II. Data mining

DM is a powerful artificial intelligence (AI) tool, which can discover useful information by analyzing data from many angles or dimensions, categorize that information, and summarize the relationships identified in the database. Subsequently, this information helps make or improve decisions. In DM solutions, algorithms can be used either independently or together to achieve the desired results. Some algorithms can explore data; others extract a specific outcome based on that data. For example, clustering algorithms, which recognize patterns, can group data into different n-groups. The data in each group are more or less consistent, and the results can help create a better decision model. Multiple algorithms, when applied to one solution, can perform separate tasks. For example, by using a regression tree method, they can obtain financial forecasts or association rules to perform a market analysis.

A large amount of data in databases today exceeds the human ability to analyze and extract the most useful information without help from automated analysis techniques. Knowledge discovery is the process of nontrivial extraction of implicit, unknown, and potentially useful information from a large database. Data mining used in KD has discovered patterns with respect to a users needs. The pattern definition is an expression in the language that describes a subset of data; an example is shown in [1].

The accurate discovery of patterns through DM is influenced by several factors, such as sample size, data integrity, and support from domain knowledge, all of which affect the degree of certainty needed to identify patterns. Typically, DM uncovers a number of patterns in a database; however, only some of them are interesting. Useful knowledge constitutes the patterns of interest to the user. It is important for users to consider the degree of confidence in a given pattern when evaluating its validity.

The KD process is interactive and examines many decisions made by the user. Loops can occur between any two steps in the process, which are needed for further iteration.

First, it is important to develop an understanding of the application domain, including relevant prior knowledge, and identify the end users goal. Second, choose a target dataset and focus on the subset of variables or data samples targeted for examination. Third, clean and preprocess the data by reducing noise, designing strategies for dealing with missing data, and accounting for time-sequence information and known changes. Fourth (the data reduction and projection phase), find useful features to represent the data such as dimensionality reduction or transformation methods. Fifth, use the goals of the KD to choose the appropriate DM strategy. Sixth, match the dataset with DM algorithms to search for patterns. Seventh, extract interesting patterns from a particular representational form or set. Eighth, interpret these mined patterns and/or return to any previous steps for an additional iteration. Finally, use the discovered knowledge by taking action and documenting or reporting the knowledge [10].

III. Educational data mining

Educational data mining is an emerging discipline, concerned with developing methods for exploring the unique types of data that come from educational settings and using those methods to better understand students and the settings which they learn in [3]. Different from data mining methods, EDM, when used explicitly, accounts for (and avail of opportunities to exploit) the multilevel hierarchy and lacks independent educational data [3].

IV. EDM Methods

Educational data mining methods come from different literature sources including data mining, machine learning, psychometrics, and other areas of computational modelling, statistics, and information visualization. Work in EDM can be divided into two main categories: 1) web mining and 2) statistics and visualization [11]. The category of statistics and visualization has received a prominent place in theoretical discussions and research in EDM [8], [7], [12]. Another point of view, proposed by Baker [3], classifies the work in EDM as follows:

1) Prediction.
   - Classification.
   - Regression.
   - Density estimation.
2) Clustering.
3) Relationship mining.
   - Association rule mining.
   - Correlation mining.
   - Sequential pattern mining.
   - Causal DM.
4) Distillation of data for human judgment.
5) Discovery with models.

Most of the above mentioned items are considered DM categories. However, the distillation of data for human judgment is not universally regarded as DM. Historically, relationship mining approaches of various types have been the most noticeable category in EDM research.

Discovery with models is perhaps the most unusual category in Bakers EDM taxonomy, from a classical DM perspective. It has been used widely to model a phenomenon through any process that can be validated in some way. That model is then used as a component in another model such as relationship mining or prediction. This category (discovery with models) has become one of the lesser-known methods in the research area of educational data mining. It seeks to determine which learning material subcategories provide students with the most benefits [13], how specific students behavior affects students learning in different ways [14], and how tutorial design affects students learning [15]. Historically, relationship mining methods have been the most used in educational data mining research in the last few years.

Other EDM methodologies, which have not been used widely, include the following:

- Outlier detections discover data points that significantly differ from the rest of the data [16]. In EDM, they can detect students with learning problems and irregular learning processes by using the learners response time data for e-learning data [17]. Moreover, they can also detect atypical behavior via clusters of students in a virtual campus. Outlier detection can also detect irregularities and deviations in the learners or educators actions with others [18].
- Text mining can work with semi-structured or unstructured datasets such as text documents, HTML files, emails, etc. It has been used in the area of EDM to analyze data in the discussion board with evaluation between peers in an ILMS [19], [20]. It has also been proposed for use in text mining to construct textbooks automatically via web content mining [21]. Use of text mining for the clustering of documents based on similarity and topic has been proposed [22], [23].
- Social Network Analysis (SNA) is a field of study that attempts to understand and measure relationships between entities in networked information. Data mining approaches can be used with network information to study online interactions [24]. In EDM, the approaches can be used for mining group activities [25].

A. Prediction

Prediction aims to predict unknown variables based on history data for the same variable. However, the input variables (predictor variables) can be classified or continue as variables. The effectiveness of the prediction model depends on the type of input variables. The prediction model is required to have limited labelled data for the output variable. The labelled data offers some prior knowledge regarding the variables that we need to predict. However, it is important to consider the effects of quality of the training data in order to achieve the prediction model.

There are three general types of predictions:

- Classification uses prior knowledge to build a learning model and then uses that model as a binary or categorical variable for the new data. Many models have been developed and used as classifiers such as logistic regression and support vector machines (SVM).
- Regression is a model used to predict variables. Different from classification, regression models predict continuous variables. Different methods of regression, such as linear regression and neural networks, have been used widely in the area of EDM to predict which students should be classified as at-risk.
- Density estimation is based on a variety of kernel functions including Gaussian functions.

Prediction methodology in EDM is used in different ways. Most commonly, it studies features used for prediction and uses those features in the underlying construct, which predicts student educational outcomes [26]. While different approaches try to predict the expected output value based on hidden variables in the data, the obtained output is not clearly defined in the labels data.

For example, if a researcher aims to identify the students most likely to drop out of school, with the large number of schools and students involved, it is difficult to achieve using traditional research methods such as questionnaires. The EDM method, with its limited amount of sample data, can help achieve that aim. It must start by defining at-risk students and follow with defining the variables that affect the students such as their parents educational backgrounds. The relation between variables and dropping out of school can be used to build a prediction model, which can then predict at-risk students. Making these predictions early can help organizations avoid problems or reduce the effects of specific issues.

Different methods have been developed to evaluate the quality of a predictor including accuracy of linear correlation, Cohens Kappa, and A [27]. However, accuracy is not recommended for evaluating the classification method because it is dependent on the base rates of different classes. In some cases, it is easy to get high accuracy by classifying all data based on the large group of classes sample data. It is also important to calculate the number of missed classifications from the data to measure the sensitivity of the classifier using recall [28]. A combined method, such as an F-measure, considers both true and false classification results, which are based on precision and recall, to give an overall evaluation of the classifier.

B. Clustering

Clustering is a method used to separate data into different groups based on certain common features. Different from the classification method, in clustering, the data labels are unknown. The clustering method gives the user a broad view of what is happening in that dataset. Clustering is sometimes known as an unsupervised classification because class labels are unknown [10].

In clustering, we have started to find data points that naturally group together to split the dataset into different groups. The number of groups can be predefined in the clustering method. Generally, the clustering method is used when the most common group in the dataset is unknown. It is also used to reduce the size of the study area. For example, different schools can be grouped together based on similarities and differences between them [29], [30].

C. Relationship mining

Relationship mining aims to find relationships between different variables in data sets with a large number of variables. This entails finding out which variables are most strongly associated with a specific variable of particular interest. Relationship mining also measures the strength of the relationships between different variables. Relationships found through relationship mining must satisfy two criteria: statistical significance and interestingness. Large amounts of data contain many variables and hence have many associated rules. Therefore, the measure of interestingness determines the most important rules supported by data for specific interests. Different interestingness measures have been developed over the years by researchers including support and confidence. However, some research has concluded that lift and cosine are the most relevant used in educational data mining[31].

Many types of relationship mining can be used such as association rule mining, sequential pattern mining, and frequent pattern mining. Association rule mining is the most common EDM method. The relationship found in association rule mining is ïf→ thenr̈ules. For example, if {Student GPA is less than two, and the student has a job} → {, the student is going to drop out of school}. The main goal of relationship mining is to determine whether or not one event causes another event by studying the coverage of the two events in the data set, such as TETRAD [32], or by studying how an event is triggered.

D. Discovery with Models

In discovery, models are generally based on clustering, prediction, or knowledge engineering using human reasoning rather than automated methods. The developed model is then used as part of other comprehensive models such as relationship mining.

E. Distillation of data for human judgement

Distillation of data for human judgment aims to make data understandable. Presenting the data in different ways helps the human brain discover new knowledge. Different kinds of data require specific methods to visualize it. However, the visualization methods used in educational data mining are different from those used in different data sets [33], [34] in that they consider the structure of the education data and the hidden meaning within it.

Distillation of data for human judgment is applied in educational data for two purposes: classification and/or identification. Data distillation for classification can be a preparation process for building a prediction model [35]; identification aims to display data such that it is easily identifiable via well known patterns that cannot be formalized [36].

As mentioned previously, there is a wide variety of methods used in educational data mining. These methods have been divided by Rayn [37] into five categories: clustering, prediction, relationship mining, discovery with models, and distillation of data for human judgement are illustrated in Table I.

V. Educational Data Mining Data and Applications

The main goal of EDM is to extract useful knowledge from educational data including student records, student usage data, inelegant tutre, and LMS systems. The extracted knowledge can improve the process of teaching and learning in the educational system[38]. It can also lead to the development of new teaching processes. Similar ideas have been applied successfully in different domains of knowledge. For example, e-commerce systems and basket analysis are popular applications in data mining [39]. They increase sales by analyzing users shopping behaviors. While it is clear that data mining methods in education have not progressed as far as they have in business [40], in the last few years, EDM has drawn more attention from researchers. Applying DM to educational data is different than it is in other domains, as defined below:

1) Objective: Applying DM methods to any specific data is led by the objectives. The main objective for using EDM is to improve teaching and learning processes. Research objectives, such as gaining a deeper understanding of the teaching and learning phenomena, occasionally influence the objectives. Applying traditional research methods to achieve goals is sometimes difficult.
2) Data: Using technology in education has led to increased data in educational systems, which differs from basic information, such as student information, because it includes more information, which is generated by different systems such as the LMS system. Applying EDM methods to educational data can make extracting specific knowledge either quite simple or more complicated such as in applying relational mining. One example would be applying relational mining to find the relation between students success in courses that contain several chapters organized into lessons, with each lesson including several concepts.
3) Techniques: The application of DM to any problem is driven by the objectives of the research and the type of data at hand. Therefore, applying data mining successfully to educational data requires specific adoption. The adoption can be for either the DM methods or pre-processing of the data. Some DM methods can be applied directly, without any modifications, and some cannot. Moreover, some DM techniques are used for specific problems in the educational domain. However, choosing certain techniques depends on the researchers perspective of the problem and the objectives of the research [41]. For example, EDM methods can improve the teaching and learning processes in the classroom, identify at-risk students, customize teaching processes, and provide recommendations to teachers and students. Most current research involves only teachers and students. However, more groups can be involved in research that has other objectives such as course development [42].

A. Data used in EDM

EDM offers a clear picture and a better understanding of learners and their learning processes. It uses DM techniques to analyze educational data and solve educational issues. Similar to other DM techniques extraction processes, EDM extracts interesting, interpretable, useful, and novel information from educational data. However, EDM is specifically concerned with developing methods to explore the unique types of data in educational settings [3]. Such methods are used to enhance knowledge about educational phenomena, students, and the settings in which they learn [4]. Developing computational

TABLE I: Educational data mining methedology categories.

Category	objectives	Key applications
prediction	Develop a model to predict some variables base on other variables. The predictor variables can be constant or extract from the data set.	Identify at-risk students. Understand student educational outcomes
Clustering	Group specific amount of data to different clusters based on the characteristics of the data. The number of clusters can be different based on the model and the objectives of the clustering process.	Find similarities and differences between students or schools. Categorized new student behavior
Relationship Mining	Extract the relationship between two or more variables in the data set.	Find the relationship between parent education level and students drooping out from school. Discovery of curricular associations in course sequences; Discovering which pedagogical strategies lead to more effective/robust learning
Discovery with Models	It aims to develop a model of a phenomenon using clustering, prediction, or knowledge engineering, as a component in more comprehensive model of prediction or relationship mining.	Discovery of relationships between student behaviours, and student characteristics or contextual variables; Analysis of research question across wide variety of contexts
Distillation of Data for Human Judgement	The main aim of this model to find a new way to enable researchers to identify or classify features in the data easily.	Human identification of patterns in student learning, behaviour, or collaboration; Labelling data for use in later development of prediction model

approaches that combine data and theory will help improve the quality of T& L processes.

The increasing use of technology in educational systems has made a large amount of data available. Educational data mining (EDM) provides a significant amount of relevant information [2]. Therefore, the main source of data used in EDM to date can be categorized as follows:

- Offline education, also known as traditional education, is where knowledge transfers to learners based on face-to-face contact. Data can be collected by traditional methods such as observation and questionnaires. It studies the cognitive skills of students and determines how they learn. Therefore, the statistical technique and psychometrics can be applied to the data.
- E-learning and learning management systems (LMS) provide students with materials, instruction, communication, and reporting tools that allow them to learn by themselves. Data mining techniques can be applied to the data stored by the systems in the databases.
- Intelligent tutoring systems (ITS) and adaptive educational hypermedia systems (AEHS) try to customize the data provided to students based on student profiles. As a result, applying data mining techniques is important for building user profiles. The data generated by that system can then assist in further research.

Based on the three categories established by Romero etl [26], we can group EDM research according to the type of data used: traditional education, web-based education (e-learning), learning management systems, intelligent tutoring systems, adaptive educational systems, tests questionnaires, texts contents, and others.

B. EDM Application

Many studies have been developed in the area of EDM. A framework for examining learners behaviors in online education videos was recommended by Alexandro & Georgios [43]. The proposed framework consisted of capturing learner performance data, designing a data model for storing the activity data, and creating modules to monitor and visualize learner viewing behavior using captured data. Researchers relied on most of the students to watch videos in the few days prior to exams or an assignment due date. Moreover, pausing and resuming was mainly observed in videos associated with an assignment. One lamentation was that the author did not study what affected learner viewing behavior or why some learners refrained from viewing online videos altogether.

In other research, Saurabh Pal [44] built a model using data mining methodologies to predict which students would likely drop out during their first year in a university program. That study used the Nave Bayes classification algorithm to build the prediction model based on the current data. The result of the system was promising for identifying students who needed special attention to reducing the dropout rate. Leila Dadkhahan [45] tried to justify what was needed for student retention in higher education institutions to reduce the number of dropouts. As a result, using data mining techniques led to increased student retention and graduation rates.

VI. Conclusions

The increased use of technology in education is generating a large amount of data every day, which has become a target for many researchers around the world; the field of educational data mining is growing quickly and has the advantage of containing new algorithms and techniques developed in different data mining areas and machine learning. The data mining of educational data (EDM) is helping create development methods for the extraction of interesting, interpretable, useful, and novel information, which can lead to better understanding of students and the settings in which they learn.

EDM can be used in many different areas including identifying at-risk students, identifying priorities for the learning needs of different groups of students, increasing graduation rates, effectively assessing institutional performance, maximizing campus resources, and optimizing subject curriculum renewal. This paper surveyed the most relevant studies carried out in the field of EDM including data used in certain studies and the methodologies employed. It also defined the most common tasks used in EDM as well as those that are the most promising for the future.

REFERENCES

[1] S.-T. Wu, "Knowledge discovery using pattern taxonomy model in text mining," 2007.
[2] J. Mostow and J. Beck, "Some useful tactics to modify, map and mine data from intelligent tutors," *Natural Language Engineering*, vol. 12, no. 02, pp. 195–208, 2006.
[3] S. K. Mohamad and Z. Tasir, "Educational data mining: A review," *Procedia-Social and Behavioral Sciences*, vol. 97, pp. 320–324, 2013.
[4] R. Baker *et al.*, "Data mining for education," *International encyclopedia of education*, vol. 7, pp. 112–118, 2010.
[5] C. Romero, S. Ventura, and P. De Bra, "Knowledge discovery with genetic programming for providing feedback to courseware authors," *User Modeling and User-Adapted Interaction*, vol. 14, no. 5, pp. 425–464, 2004.
[6] N. S. Raghavan, "Data mining in e-commerce: A survey," *Sadhana*, vol. 30, no. 2-3, pp. 275–289, 2005.
[7] C. Romero, S. Ventura, M. Pechenizkiy, and R. S. Baker, *Handbook of educational data mining*. CRC Press, 2010.
[8] R. S. Baker and K. Yacef, "The state of educational data mining in 2009: A review and future visions," *JEDM-Journal of Educational Data Mining*, vol. 1, no. 1, pp. 3–17, 2009.
[9] F. Castro, A. Vellido, À. Nebot, and F. Mugica, "Applying data mining techniques to e-learning problems," in *Evolution of teaching and learning paradigms in intelligent environment*, pp. 183–221, Springer, 2007.
[10] U. Fayyad, G. Piatetsky-Shapiro, and P. Smyth, "The kdd process for extracting useful knowledge from volumes of data," *Communications of the ACM*, vol. 39, no. 11, pp. 27–34, 1996.
[11] T. Barnes, M. Desmarais, C. Romero, and S. Ventura, *in Proc*. Educational Data Mining 2009:2nd International Conf, 2009.
[12] S. L. Tanimoto, "Improving the prospects for educational data mining," in *Track on Educational Data Mining, at the Workshop on Data Mining for User Modeling, at the 11th International Conference on User Modeling*, pp. 1–6, 2007.
[13] J. E. Beck and J. Mostow, "How who should practice: Using learning decomposition to evaluate the efficacy of different types of practice for different types of students," in *Intelligent tutoring systems*, pp. 353–362, Springer, 2008.
[14] M. Cocea, A. Hershkovitz, and R. S. Baker, "The impact of off-task and gaming behaviors on learning: immediate or aggregate?," 2009.
[15] H. Jeong and G. Biswas, "Mining student behavior models in learning-by-teaching environments.," in *EDM*, pp. 127–136, Citeseer, 2008.
[16] V. J. Hodge and J. Austin, "A survey of outlier detection methodologies," *Artificial Intelligence Review*, vol. 22, no. 2, pp. 85–126, 2004.
[17] C. C. Chan, "A framework for assessing usage of web-based e-learning systems," in *Innovative Computing, Information and Control, 2007. ICICIC '07. Second International Conference on*, pp. 147–147, Sept 2007.
[18] M. Muehlenbrock, "Automatic action analysis in an interactive learning environment," in *Proceedings of the 12 th International Conference on Artificial Intelligence in Education*, pp. 73–80, 2005.
[19] M. Ueno, "Data mining and text mining technologies for collaborative learning in an ilms" ssamurai"," in *Advanced Learning Technologies, 2004. Proceedings. IEEE International Conference on*, pp. 1052–1053, IEEE, 2004.
[20] L. P. Dringus and T. Ellis, "Using data mining as a strategy for assessing asynchronous discussion forums," *Computers & Education*, vol. 45, no. 1, pp. 141–160, 2005.
[21] J. Chen, Q. Li, L. Wang, and W. Jia, "Automatically generating an e-textbook on the web," in *Advances in Web-Based Learning–ICWL 2004*, pp. 35–42, Springer, 2004.
[22] J. Tane, C. Schmitz, and G. Stumme, "Semantic resource management for the web: an e-learning application," in *Proceedings of the 13th international World Wide Web conference on Alternate track papers & posters*, pp. 1–10, ACM, 2004.
[23] C. Tang, R. W. Lau, Q. Li, H. Yin, T. Li, and D. Kilis, "Personalized courseware construction based on web data mining," in *Web Information Systems Engineering, 2000. Proceedings of the First International Conference on*, vol. 2, pp. 204–211, IEEE, 2000.
[24] J. Scott, *Social network analysis*. Sage, 2012.
[25] P. Reyes and P. Tchounikine, "Mining learning groups' activities in forum-type tools," in *Proceedings of th 2005 conference on Computer support for collaborative learning: learning 2005: the next 10 years!*, pp. 509–513, International Society of the Learning Sciences, 2005.
[26] C. Romero, S. Ventura, P. G. Espejo, and C. Hervás, "Data mining algorithms to classify students.," in *EDM*, pp. 8–17, 2008.
[27] A. P. Bradley, "The use of the area under the roc curve in the evaluation of machine learning algorithms," *Pattern recognition*, vol. 30, no. 7, pp. 1145–1159, 1997.
[28] B. Liu, *Web data mining: exploring hyperlinks, contents, and usage data*. Springer Science & Business Media, 2007.
[29] C. R. Beal, L. Qu, and H. Lee, "Classifying learner engagement through integration of multiple data sources," in *Proceedings of the National Conference on Artificial Intelligence*, vol. 21, p. 151, Menlo Park, CA; Cambridge, MA; London; AAAI Press; MIT Press; 1999, 2006.
[30] S. Amershi and C. Conati, "Automatic recognition of learner groups in exploratory learning environments," in *Intelligent Tutoring Systems*, pp. 463–472, Springer, 2006.
[31] A. Merceron and K. Yacef, "Interestingness measures for associations rules in educational data.," *EDM*, vol. 8, pp. 57–66, 2008.
[32] C. Wallace, K. B. Korb, and H. Dai, "Causal discovery via mml," in *ICML*, vol. 96, pp. 516–524, Citeseer, 1996.
[33] A. Hershkovitz and R. Nachmias, "Developing a log-based motivation measuring tool.," in *EDM*, pp. 226–233, Citeseer, 2008.
[34] J. Kay, N. Maisonneuve, K. Yacef, and P. Reimann, "The big five and visualisations of team work activity," in *Intelligent tutoring systems*, pp. 197–206, Springer, 2006.
[35] R. S. d Baker, A. T. Corbett, and V. Aleven, "More accurate student modeling through contextual estimation of slip and guess probabilities in bayesian knowledge tracing," in *Intelligent Tutoring Systems*, pp. 406–415, Springer, 2008.
[36] A. T. Corbett and J. R. Anderson, "Knowledge tracing: Modeling the acquisition of procedural knowledge," *User modeling and user-adapted interaction*, vol. 4, no. 4, pp. 253–278, 1994.
[37] R. Baker *et al.*, "Data mining for education," *International encyclopedia of education*, vol. 7, pp. 112–118, 2010.
[38] C. Romero, S. Ventura, and P. De Bra, "Knowledge discovery with genetic programming for providing feedback to courseware authors," *User Modeling and User-Adapted Interaction*, vol. 14, no. 5, pp. 425–464, 2004.
[39] N. S. Raghavan, "Data mining in e-commerce: A survey," *Sadhana*, vol. 30, no. 2-3, pp. 275–289, 2005.
[40] C. Romero, S. Ventura, M. Pechenizkiy, and R. S. Baker, *Handbook of educational data mining*. CRC Press, 2010.
[41] M. Hanna, "Data mining in the e-learning domain," *Campus-wide information systems*, vol. 21, no. 1, pp. 29–34, 2004.
[42] C. Romero and S. Ventura, "Educational data mining: a review of the state of the art," *Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on*, vol. 40, no. 6, pp. 601–618, 2010.
[43] K. Alexandros and E. Georgios, "A framework for recording, monitoring and analyzing learner behavior while watching and interacting with online educational videos," in *Advanced Learning Technologies (ICALT), 2013 IEEE 13th International Conference on*, pp. 20–22, IEEE, 2013.
[44] S. Pal, "Mining educational data using classification to decrease dropout rate of students," *arXiv preprint arXiv:1206.3078*, 2012.
[45] L. Dadkhahan and M. A. Al Azmeh, "Critical appraisal of data mining as an approach to improve student retention rate," *International Journal of Engineering and Innovative Technology (IJEIT) Volume*, vol. 2.

Exploiting Document Level Semantics in Document Clustering

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***Abstract*—Document clustering is an unsupervised machine learning method that separates a large subject heterogeneous collection (Corpus) into smaller, more manageable, subject homogeneous collections (clusters). Traditional method of document clustering works around extracting textual features like: terms, sequences, and phrases from documents. These features are independent of each other and do not cater meaning behind these word in the clustering process. In order to perform semantic viable clustering, we believe that the problem of document clustering has two main components: (1) to represent the document in such a form that it inherently captures semantics of the text. This may also help to reduce dimensionality of the document and (2) to define a similarity measure based on the lexical, syntactic and semantic features such that it assigns higher numerical values to document pairs which have higher syntactic and semantic relationship. In this paper, we propose a representation of document by extracting three different types of features from a given document. These are lexical α, syntactic β and semantic γ features. A meta-descriptor for each document is proposed using these three features: first lexical, then syntactic and in the last semantic. A document to document similarity matrix is produced where each entry of this matrix contains a three value vector for each lexical α, syntactic β and semantic γ. The main contributions from this research are (i) A document level descriptor using three different features for text like: lexical, syntactic and semantics. (ii) we propose a similarity function using these three, and (iii) we define a new candidate clustering algorithm using three component of similarity measure to guide the clustering process in a direction that produce more semantic rich clusters. We performed an extensive series of experiments on standard text mining data sets with external clustering evaluations like: F-Measure and Purity, and have obtained encouraging results.**

Keywords*—Document Clustering; Text Mining; Similarity Measure; Semantics

I. Introduction

Document clustering [9] can be defined as an unsupervised learning approach, which clusters the document repository into meaningful smaller and manageable sub-collections. These resultant sub-collections contain high intra-cluster similarity (that is, the documents in a single cluster are mainly similar in some sense), and low inter-cluster similarity (documents in two sub-collections are largely dissimilar). It has found its niche in management of large document repositories. Learning the common features for grouping implicitly is the main spirit of document clustering. Traditionally, document clustering algorithms utilized simple features present in the documents like (word, phrases and sequence of words) to cluster the documents. These simple features are independent of document context and thus the semantic of the document cannot be incorporated into the clustering process. In order to perform semantic viable clustering, we believe that the problem of document clustering has two main aspects: (1) to represent the document in such a form that it inherently captures semantics of the text. This may also help to reduce dimensionality of the document . Other, (2) to define a similarity measure based on the semantic representation such that it assigns higher numerical values to document pairs which have higher semantic relationship. In general, the degree of similarity between documents is measured by the words and sentences or meaning of the document. A similarity measure should also address the problem of partial matching of documents. Several efforts have been made to address the problem of document partial matching, using the lexical features from a document like: keywords, concepts, nouns, verb etc. Documents are modeled in such a way that it allows the similarity methods to compute partial contribution of these individual units in the similarity values. The overall document similarity is obtained as a function of those partial measures. We have observed that while doing this partial document matching towards similarity function, there are two problems that have not been handled in previous works (i) Word Order problem i.e, In Human spoken languages, the selection of words is mainly base on the contextual information being contained in the document. Similarly, the order of the words appearing in the text influences the meaning of the text. For example, the sentences "A hires B" and "B hires A" are composed by selecting the same words, but the order completely changes their meaning and (ii) Semantic matching i.e, Sentences with the same meaning but different words. For example, the sentences "Joe is an intelligent boy" and "Joe is a smart lad" have similar meaning, if the context in which they appear does not change much.

According to the work in [5], the paper proposed a three-layer representation of documents. Unlike sentences, we apply these three layer transformation on an entire document. These layers are lexical, syntactic and semantic layers. Each layer extracts specific features from the same document. The lexical analysis is performed in the first layer in which we extract the bag of word vectors from the documents. Documents are preprocessed by removing stop words and stemming. The syntactic layer uses relations (predicates) extracted from the RDFs of the documents to handle word order problem. The RDFs of the documents are generated using an online tool Alchemy API [13]. The semantic layer employs the Semantic Role Annotation (SRA) to handle the semantics problem. The SRA analysis is done using Fred API [11] which returns the meaning of the actions, the actor who performs the action, and the object/actor on which the action is being performed. FRED is a tool for automatically producing RDF/OWL ontology's and linked data from natural language sentences. The method is based on combinatorial Categorical Grammar, Discourse Representation Theory, Linguistic Frames, and Ontology Design Patterns. Results are enriched with Named Entity Resolution (NER) and Word-Sense Disambiguation (WSD). Below is an example based on a sample document; the three representations are presented next to each other.
Below is an example of a simple sentence;

D1 = "Pakistani boys love to play cricket and hockey"

Lexical Feature:
{Pakistani, Boy, Love, Cricket, Hockey}

Syntactic Feature:

```
<relation>
        <sentence>Pakistani boys love cricket and hockey.</sentence>
        <subject>
          <text>Pakistani boys</text>
        </subject>
        <action>
          <text>love</text>
          <lemmatized>love</lemmatized>
          <verb>
            <text>love</text>
            <tense>present</tense>
          </verb>
        </action>
        <object>
          <text>cricket and hockey</text>
        </object>
</relation>
```

Semantic Feature:

Activity	{Hockey, Cricket}
Boy	{PakistaniBoy}
Event	{Love}
Experiencer_focus	{Love}
supersense-noun_act	{Hockey, Cricket}

Fig. 1. Three layer representation of a sample document

Below is an example document from NEWS20 data set, the meta-descriptor clearly contains three types of features just after another. Here is an example from document 103122;

D2 = "Most people who go fast wear goggles. So do most of helmetless motorcyclists"

Lexical Feature:
{Most, People, Who, Go, Fast, Wear, Goggles, So, Do, Helmetless, Motorcyclist}

Syntactic Feature:

```
<relation>
    <sentence> Most people who go fast wear goggles.</sentence>
    <subject>
      <text>Most people</text>
    </subject>
    <action>
      <text>go</text>
      <verb>
        <text>go</text>
        <tense>present</tense>
      </verb>
    </action>
    <object>
      <text>fast wear goggles</text>
    </object>
</relation>
```

```
<relation>
    <sentence> So do most of helmetless motorcyclists.</sentence>
    <subject>
      <text>So</text>
    </subject>
    <action>
      <text>do</text>
      <verb>
        <text>do</text>
        <tense>present</tense>
      </verb>
    </action>
    <object>
      <text>most helmetless motorcyclists.</text>
    </object>
</relation>
```

Semantic Feature:

Event	{Do, Go}	Quality	{Most}
PhysicalObject	{Goggles, Wear}	Motorcyclist	{HelmetlessMotorcyclist}

Fig. 2. Three layer representation of an example document 103122

We believe that the major confusion in clustering process is just because we consider lexical features alone. The syntactic and semantic features may guide us on the right decision to merge two documents or not, hence a good clustering arrangement is learned. We have carried out an extensive set of experiments with standard text mining data sets. Our proposed approach clearly surpasses the traditional document clustering methods on evaluation like: F-Score and Purity. The paper organized as follows: Section 2 discusses the related work in area of text document clustering, specifically in the realm of semantic based document clustering. Section 3 describes our proposed approach along with some examples. Section 4 presents the experimental setup, data sets, comparative algorithms, and evaluation measures. Section 5 discusses the experimental results. Conclusion is presented in section 6.

II. The Literature Review

Data clustering [9] is an unsupervised technique which creates succinct sub-groups from the data for discovering valuable knowledge. Document clustering is a specialized data clustering problem where the objects are in the form of documents. The objective of the clustering process is to group the similar documents and separate different ones. The difficult part of this unsupervised task is to learn how many clusters of such groups exist in a given data set. Document Clustering aims to discover natural grouping among documents in such a way that documents within a cluster are similar (high intra-cluster similarity) to one another and are dissimilar to documents in other clusters (low inter cluster similarity). Exploring, analyzing, and correctly classifying the unknown natures of data in a document without supervision is the major requirement of document clustering method. Clustering is an effective method for search computing [1]. It offers the possibilities like:

grouping similar results [3], comprehending the links between the results [8] and creating the succinct representation and display of search results[3,4]. Document clustering has three main steps: (i) document representation model, (ii) similarity measure between a pair of documents in selected form of representation and (iii) clustering algorithm that produce the final clustering arrangement. Document representation is very sensitive for the task of document clustering. Traditionally, document clustering algorithms mainly use features like: words [7], phrases [2], and sequences [6, 10] from the documents to perform clustering. These algorithms generally apply simple feature extraction techniques that are mainly based on feature counting frequency distribution of the features. The approach in [6] proposed a frequent itemset-based representation of documents for clustering (FIHC). Motivated from the idea of market basket analysis, the authors considered a document as basket and the terms used in the document are considered as itemsets present in it. A representation based on frequent items (frequent phrases) is proposed. The work in [10] proposed two solutions to document representations (i) frequent word sequences (CFWS) and (ii) frequent word meaning sequences (CFWMS). The two approaches first parses a given document to get the frequent word sequences of some arbitrary length (2-word set for their experiment). The first uses the frequent word sequences and the second uses an external lexical database WordNet [4] to annotate the word with their meaning to cover the word meaning problem, such as synonymy, polysemy, and hyponymy/hypernymy. Their experimental studies have shown an improvement in F-Measure for both CFWS and CFWMS over FIHC. Although these approaches use phrases or order of words in representation of documents, their results are still fallible on semantics of the clusters produced. These techniques simply perform clustering independent of the context. Document written in human language contains a context and words that are largely depending on it. A more recent approach to represent a document is based on dependency graph (DGDC), proposed in [14]; each document is parsed to form a dependency graph. This dependency graph captures the semantic representation of documents; thus, it offers more semantic rich clustering. It also introduced a novel similarity measure based on common features of the two corresponding graphs of the documents. One more recent approach to capture semantic representation of documents in document representation model is introduced in [12] in which the authors proposed a topic maps based representation by using an online tool Wandora for extracting topics from a document. They also reported encouraging results for document clustering based on semantic notions. We conclude that there are features like frequent item sets, common frequent sequences or word meaning sequences, dependency graphs, and topic maps that can be used to reduce the dimensionality of document space and at the same time offer more semantics in representations over simple Bag-of-words (BOW); These approaches still fail to incorporate semantics on larger scale. The phrases or sequence are a good measure for identifying semantics of the text. We believe that a sentence specific measure will be more semantic rich, and extending a sentence level similarity to a complete document is a challenging aspect of semantic oriented document clustering. A sentence similarity can easily capture similarity between phrases and sequences, but this similarity should also address the issue of partial information like: when one sentence splits into two or more short texts and phrases that contain two or more sentences, it should assign partial score to matched phrases or sequences. The score should directly proportionate to a number of such units found in the two sentences. In [5] authors describe a sentence similarity measure that uses three-layer of sentences meta descriptor to capture the semantic in the similarity measure. We have been motivated by this idea and extended it to a full document for eventually performing the task of clustering. A document is transformed into three meta-representations based on lexical, syntactic and semantic layers. A similarity measure for each representation is defined based on features extracted from each layer. Cosine similarity is used for each pair of documents in all the three layers; hence, we get three similarity values in each of the three layers, that is lexical, syntactic and semantic meta-descriptor. Final document clustering is performed on N x N matrix(containing the vectors$< \alpha, \beta, \gamma >$ from three layers) by candidate based document clustering algorithm. We have conducted an extensive set of experiments with standard text mining data sets. Our proposed approach clearly surpasses the traditional document clustering methods on evaluation like: F-Score and Purity.

III. EXPLOITING DOCUMENT LEVEL SEMANTICS IN DOCUMENT CLUSTERING

A. Document Representation

In this paper, we propose a representation of each document based on three levels, namely lexical, syntactic and semantic levels. Each level produces a separate document-to-document similarity score. We generate a vector of similarity scores based on these three levels i.e.

$$Vector(D_a \leftarrow D_b) = Sim < \alpha, \beta, \gamma > \tag{1}$$

Where $\alpha,\ \beta\ and\ \gamma$ are the similarity scores of lexical, syntactic and semantic level from Document a to Document b.

1) Extraction of lexical features: Bag of Words are extracted as the features of the document. From all the documents in the set, a dictionary of words (vector) is built. For each document a vector is built which contains the common tokens between the document and the dictionary. The vector contains values formed by calculating $TF * IDF$ for each token. $TF * IDF$ is a numerical statistic that is intended to reflect how important a word is to a document in a collection or corpus.
Stop word removal rules out words with little representative value to the document, e.g. articles and pronouns, and the punctuation.
Stemming is a pre-processing service, which translates the tokens in its basic form. For instance, plural words are made singular and all verb tenses and persons are exchanged by the verb infinitive.

2) Extraction of syntactic features: Alchemy API has been used for all the documents to extract the Subject, Action and Object of each sentence in every document. The syntactic analysis represents an order relation among the extracted features of the documents. It describes the syntactic structures of the language; and decomposes the text into syntactic units in order to know the arrangements of syntactic elements. Such kind of relations could be used in applications, as for instance,

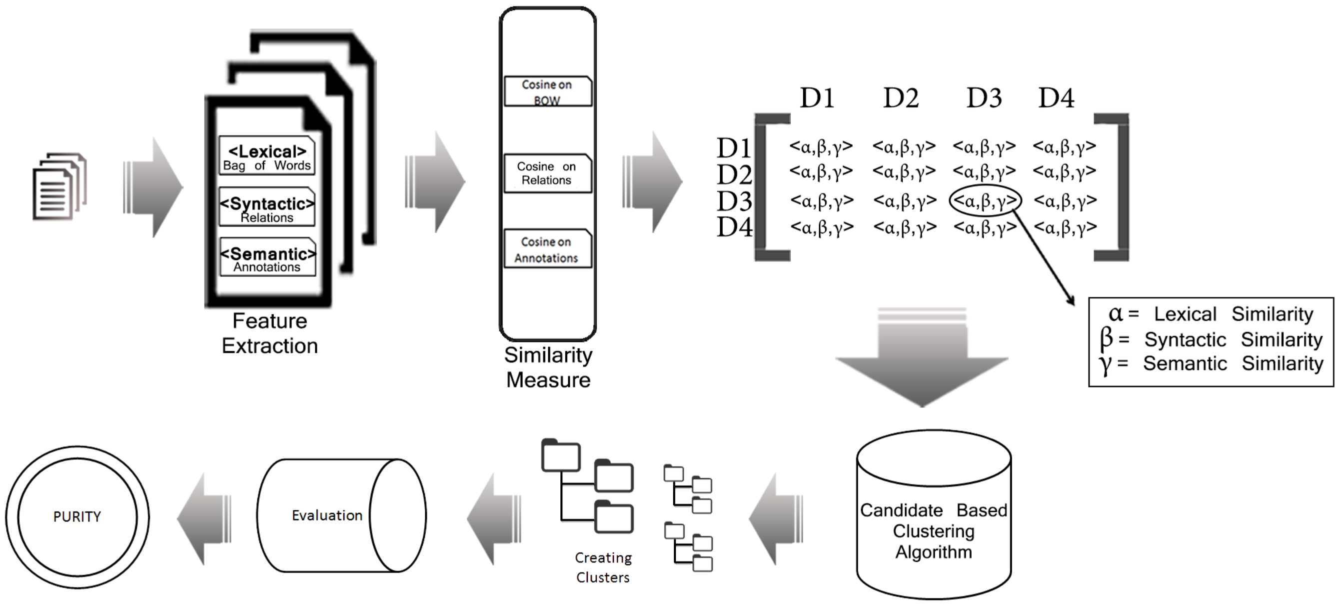

Fig. 3. DLS-DC approach

automatic text summarization, text categorization, information retrieval, etc.

3) Extraction of semantic features: Semantic representation is built using Fred API. The API gives a semantic rich representation of a document in terms of RDFs. FRED is a tool to automatically transform knowledge extracted from text into RDF and OWL, i.e. it is a machine reader for the Semantic Web. It is event-centric; therefore it natively supports event extraction. The API uses word sense disambiguation. FRED has got precision, recall, and accuracy largely better than the other tools attempting event extraction.
Semantic annotating features are then extracted using SPARQL queries and saved as triples. For example, in a certain document, the object Event is the annotating feature for its subjects call, do, see and think, which means that all these words graphically point to the object Event.

B. Similarity Measures

1) Lexical similarity: The similarity is calculated using Cosine Similarity measure which takes two document vectors and returns a similarity score between the documents. The vector size of each document is the size same as of the dictionary vector. The similarity is calculated using the formula below;

$$Sim(D_a \leftarrow D_b) = Cosine(< tf.idf\ V > D_a, < tf.idf\ V > D_b) \quad (2)$$

Where 'V' is $TF * IDF$ Vector.

2) Syntactic similarity: Word Order Problem has been handled by assigning equal weights to each of the three features given by Alchemy. Predicate is checked before the Subject and Object. For example, in the sentences "Joe killed Mary" and "Mary killed Joe", the predicate 'killed' is similar. As a result, it is assigned a weight of $1 * 0.33$, whereas 'Joe' as a subject in the first sentence does not match with 'Mary' as a subject in the second sentence and same goes for 'Mary' as an object in the first sentence with 'Joe' as an object in the second. Consequently, they are assigned a weight of $0 * 0.33$ each. This gives us $0.33 + 0 + 0 = 0.33$ as a similarity score between the two sentences.

This was for sentence to sentence measure. On document to document, the similarity is calculated through the following formula:

$$Sim(D_a \leftarrow D_b) = \frac{\Sigma_{i=1}^{n} max(Sim(S_{a_i} \leftarrow S_{b_i} \dots S_{b_n}))}{max(D_a.size, D_b.size)} \quad (3)$$

Where S_{a_i} is the i^{th} sentence of document 'a' and $S_{b_i}...S_{b_n}$ are all the sentences in document 'b'. Every sentence of document 'a' is matched to every sentence in document 'b' and the maximum similarity scores of all sentences are averaged by the number of sentences of the document which has larger number of sentences in it.

3) Semantic similarity: Event {Call, Do, See, Think}, where Event is the annotating feature and the words in the braces are its subjects, i.e. all the incoming nodes to the object.

Similarly, there are objects (annotating features), generated by the FRED, as Activity, For and others, depending upon the document. To build semantic representation of a document, all the annotating features along with their subjects are extracted using SPARQL.

While comparing two documents for similarity, the algorithm first checks if the object (annotating feature) of one document matches with the other. If it matches, the similarity is computed on the subjects of both the objects using Cosine Similarity measure. All the subjects in all annotating features are matched based on the condition above and the similarities of all the features are summed up. The document to document similarity score is calculated by dividing the final similarity sum with the average of the total number of objects in both the documents. The above representation also captures word sense disambiguation. For Example, **D3: "I am doing research on Semantics. D4: "My research is on Semantics**

The semantic score for the above documents will be 1 by using this representation. Below is an algorithm for document to document similarity calculation.

Algorithm 1 Document to Document Similarity

Require: Documents N
Ensure: $Similarity\ Matrix\ M\ containing$
  $Vector\ V < \alpha, \beta, \gamma >$
  $Documents\ D[] \leftarrow N$
  $X \leftarrow SELECT\ ?subject\ ?predicate\ ?object$
  $WHERE\{?subject\ ?predicate\ ?object\ .\}$
  for $i\ \dots\ N.length$ **do**
    $A_{lex} \leftarrow Terms(D[i])$
    $A_{syn} \leftarrow Alchemy(D[i])$
    $A_{sem} \leftarrow getAnnotatingFeatures(Q(D[i]))$
    for $j\ \dots\ N.length$ **do**
      $B_{lex} \leftarrow Terms(D[j])$
      $B_{syn} \leftarrow Alchemy(D[j])$
      $B_{sem} \leftarrow getAnnotatingFeatures(Q(D[j]))$
      $\alpha \leftarrow CosineSim(A_{lex},\ B_{lex})$
      $\beta \leftarrow CosineSim(A_{syn},\ B_{syn})$
      for all $s_1 \in A_{sem}.keySet()$ **do**
        for all $s_2 \in B_{sem}.keySet()$ **do**
          if $s_1 == s_2$ **then**
            $\gamma += Cosine(A_{sem}.get(s_1),\ B_{sem}.get(s_2))$
          end if
        end for
      end for
      $\gamma = \gamma\ /\ Avg(A_{sem}.keySet().size(),$
      $B_{sem}.keySet().size())$
      $V_{i,j} \leftarrow V < \alpha, \beta, \gamma >$
      $M_{i,j} \leftarrow V_{i,j}$
    end for
  end for

C. Candidate Based Clustering Algorithm

Here is an algorithm for candidate based document clustering.

The algorithm takes a similarity matrix of size $D \times D$ containing a vector of size three on each value. M_{prev} and M_{curr} are the matrices taken for keeping the record of updated matrix each time after the matrix is merged in each iteration. DocPair is a pair of two documents that is extracted through the matrix containing the vectors. Example of a DocPair 103124 - 102616. C_{pair} is the final Cluster Pair decided after making the candidate based decisions. The C_{pair} is sent to the MERGE and UPDATE function which reduces the matrix by one column and one row and updates the values of the matrix using Average Linkage Strategy. Clusters is a list of Clusters that initially contains D clusters and the two Clusters based upon the decision are merged using ClustersUpdate function in order to get the final K level clusters.

Algorithm 2 Candidate Clustering Algorithm

Require: $Similarity\ Matrix\ M\ containing\ Vector$
  $V < \alpha, \beta, \gamma >, ClusterLevels\ K\ ,\ DocumentIDs\ D$
Ensure: $Partition\ of\ D\ with\ K\ classes$
  $M_{prev} \leftarrow M$
  $M_{curr} \leftarrow M$
  $Clusters \leftarrow D$
  for $i\ \dots\ D.length - K$ **do**
    $DocPair_{lex} \leftarrow M.extractMax(V(\alpha))$
    $DocPair_{syn} \leftarrow M.extractMax(V(\beta))$
    $DocPair_{sem} \leftarrow M.extractMax(V(\gamma))$
    $ClusterPair\ C_{pair} \leftarrow DocPair_{lex}$
    if $DocPair_{lex} == DocPair_{syn}$ **then**
      $C_{pair} \leftarrow DocPair_{lex}\ OR\ DocPair_{syn}$
    end if
    if $DocPair_{syn} == DocPair_{sem}$ **then**
      $C_{pair} \leftarrow DocPair_{syn}\ OR\ DocPair_{sem}$
    end if
    if $DocPair_{lex} == DocPair_{sem}$ **then**
      $C_{pair} \leftarrow DocPair_{lex}\ OR\ DocPair_{sem}$
    end if
    $M_{prev} \leftarrow M_{curr}$
    $M_{curr} \leftarrow MERGE(M_{prev}\ ,\ C_{pair}\ )$
    $M_{curr} \leftarrow UPDATE(M_{prev}\ , C_{pair}\ ,\ AveregeLinkage)$
    $ClustersUpdate(C_{pair}.leftChild\ ,\ C_{pair}.rightChild)$
  end for

IV. EXPERIMENTAL STUDIES

A. Implementation of Algorithm

The proposed algorithmic approach has been compared with a number of recently proposed document clustering algorithms on the popular standard dataset of NEWS20 and Reuters21578 for the problem of document clustering. The DLS-DC is implemented in Java programming language. The experiment is executed on a Dell 5547 Notebook with Intel Core i7 processor and 8GB of RAM with 1TB of Hard Disk Storage.

B. Datasets

We have used the popular text data sets NEWS20 and Reuters21578 for our experiments.

Data Set	Data Sources	No. of Docs	No. of Classes
D1	NEWS20	50	5
D2	NEWS20	100	10
D3	NEWS20	200	15
D4	NEWS20	400	15
D5	NEWS20	813	20
D6	Reuters21578	797	15

TABLE I. SAMPLE DATA SETS FROM NEWS20 AND REUTERS

C. Evaluation

We justify the effectiveness of our proposed method by using standard cluster quality measures like

1) F-Measure: The F-measure uses a combination of precision and recall values of clusters. The F-measure, $F(i, j)$, of a class

$$F(i,j) = \frac{2 * prec(i,j) * rec(i,j)}{prec(i,j) * rec(i,j)} \quad (4)$$

The F-measure for entire clustering result is defined as

$$F = \sum_{i}^{n} \frac{n_i}{n} max(F(i,j)) \quad (5)$$

2) Purity: Purity can be defined as the maximal precision value for each class j. We compute the purity for a cluster j as:

$$Purity(j) = \frac{1}{c_j} max(c_{ij}) \quad (6)$$

We then define purity of the entire clustering result as:

$$Purity = \sum_{j}^{n} \frac{c_j}{N} purity(j) \quad (7)$$

3) Baseline: The baseline for this experiment is set using the bag-of-words representation for documents. We are using $TF * IDF$ based representation for document vectors and cosine measure to create a clustering arrangement for our baseline.

D. Comparative Work

We would like to compare our proposed approach to the three recent approaches that claim that they produce semantic rich clustering. The approach in [6] proposed a frequent item set-based representation of documents for clustering (FIHC), the second is from [10] from where we only compare with frequent word sequences (CFWS), and third and final is from [12] where authors used topic maps based representation of documents. We have implemented the proposed approaches as described in [6, 10, 12].

V. RESULT & DISCUSSION

In this paper, we present a new approach to cluster the documents based on semantic rich features using a vector representation. The inferred knowledge from the three representations is used to define the similarity measures between the pair of documents. Each of these measures is used in a matrix with each value containing a vector of size three to cluster the set of documents by using Candidate Based Clustering Algorithm CBCA. First, we would like to discuss F-measure of Hierarchical Clustering on individual levels with Candidate Based Clustering Algorithm CBCA.

DataSets	Lex	Syn	Sem	CBCA
D1	0.55	0.29	0.35	0.67
D2	0.34	0.18	0.22	0.42
D3	0.41	0.22	0.27	0.5
D4	0.49	0.26	0.32	0.6
D5	0.53	0.28	0.34	0.65
D6	0.75	0.49	0.61	0.89

TABLE II. F-MEASURE FROM THE EXPERIMENTS

Results of F-Measure on different layers for Hierarchical Clustering on individual levels with Candidate Based Clustering Algorithm CBCA.

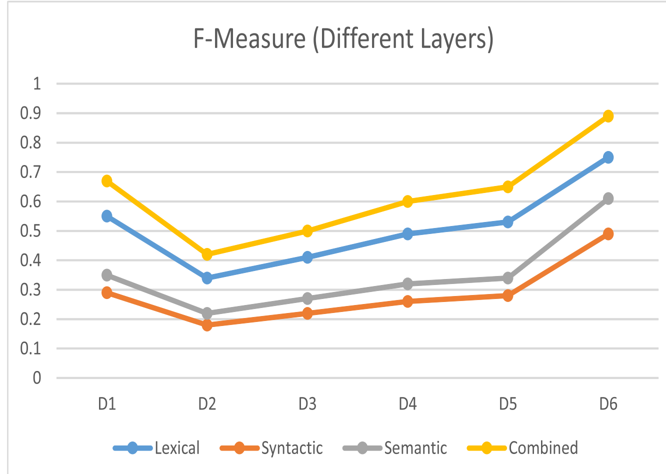

Fig. 4. F-measure from the experiments

We next want to discuss the purity of Hierarchical Clustering on individual levels with Candidate Based Clustering Algorithm CBCA.

DataSets	Lex	Syn	Sem	CBCA
D1	0.58	0.33	0.39	0.71
D2	0.4	0.23	0.27	0.49
D3	0.46	0.26	0.31	0.56
D4	0.52	0.3	0.35	0.63
D5	0.55	0.31	0.37	0.67
D6	0.72	0.41	0.42	0.88

TABLE III. PURITY FROM THE EXPERIMENTS

Results of Purity on different layers for Hierarchical Clustering on individual levels with Candidate Based Clustering Algorithm CBCA.

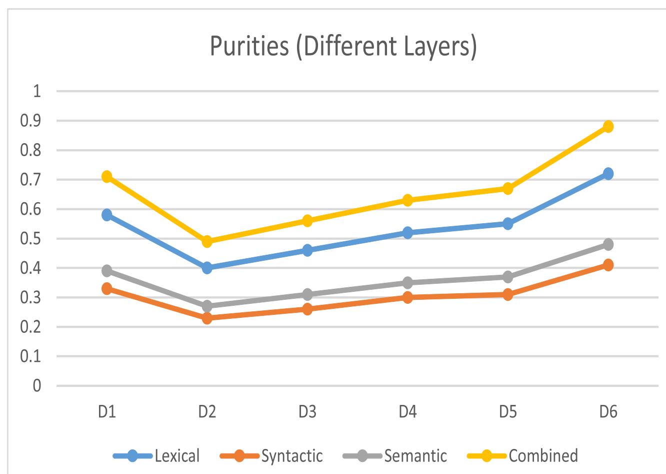

Fig. 5. Purity from the experiments

The higher purity values by candidate based clustering algorithm is an indication of producing high-quality clusters which is again due to the fact that a combined representation scheme is used for clustering. The experimental results show that DLS-DC performs better than comparative algorithms of this study in terms of quality of the clusters produced. Increased cluster purity clearly establishes the fact that the features extracted from the three representations capture the semantics of the documents. The three approaches FIHC [6], CFWS [10] and TMHC [12] produced F-measure for the data sets (See Table IV).

DataSet	FIHC	CFWS	TMHC	CBCA
D1	0.55	0.62	0.63	0.67
D2	0.54	0.58	0.66	0.42
D3	0.48	0.44	0.58	0.5
D4	0.43	0.44	0.58	0.6
D5	0.41	0.39	0.53	0.65
D6	0.88	0.68	0.89	0.89

TABLE IV. F-MEASURE FROM DIFFERENT APPROACHES ON TEST DATASETS

The proposed approach clearly had shown improvement in most of test cases. This is due to the fact that the multiple representations of documents in the collection capture the semantics in a better way, and are able to produce high F-Measure which is an indication of balance precision and recall (See Figure 6).

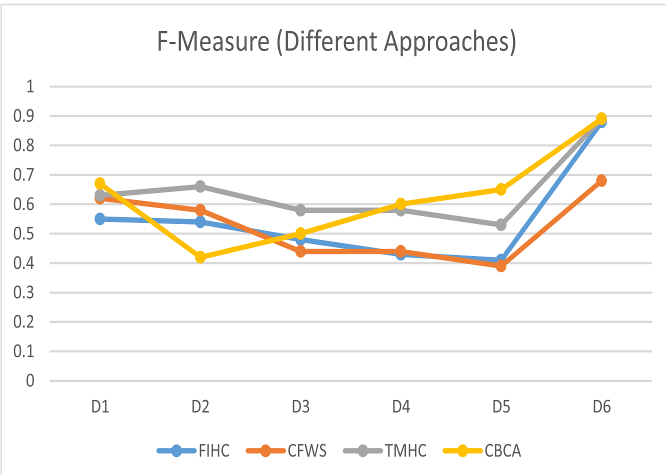

Fig. 6. F-measure from different approaches on test datasets

Similarly, another evaluation that is very instrumental in identifying the better clustering is purity. The proposed approach produces better purity values when compared to the comparative algorithms (See Table V).

DataSet	FIHC	CFWS	TMHC	CBCA
D1	0.6	0.62	0.66	0.71
D2	0.6	0.62	0.64	0.49
D3	0.58	0.6	0.68	0.56
D4	0.57	0.6	0.64	0.63
D5	0.56	0.58	0.6	0.67
D6	0.78	0.72	0.81	0.88

TABLE V. PURITY FROM DIFFERENT APPROACHES ON TEST DATASETS

The purity with the proposed approach DLS-DC indicates that our idea of different representation of the same document (with different focus) has produced better understanding at representation level. Hence, the automatic clustering process implicitly identifies the common attributes to produce better purity values (See Figure 7). In most of the approaches DLS-DC is performing well as evident in results of purity and F-Measure. The dataset classes D1 to D5 are created manually from the complete dataset of news20.Due to confusion between documents in dataset classes D2 and D3, the graph shows slightly lower purity and F-measure values.

VI. CONCLUSION

We propose an approach that exploits document level semantics in document clustering. The representation of document comprises of three levels namely: lexical, syntactic and semantic, that are defined for the document. In lexical representation, we only use lexical features. The syntactic representation comprises of syntactical features through transformation using Alchemy API. We also cater Word Order Problem in Syntactic analysis. The Semantic representation is defined by FRED API and RDF based annotated structures that are extracted from each document by using SPARQL queries and the similarity is calculated by using the algorithm defined. Clustering is performed by using a candidate based clustering approach. The proposed approach clearly surpasses purity and F-measure in comparison to recently proposed approaches like (FIHC, CFWS and TMHC), which is an indication of better clustering results. We like to extend this research in a number of ways. First, we would like to introduce document constraints in the clustering approach. Secondly, we would like to introduce some methods to increase the weight given to the semantic representation, while making decisions in the clustering algorithm. Moreover, we would like to further investigate the combined representation of document using the three representations because it seems a more challenging aspect for good clustering.

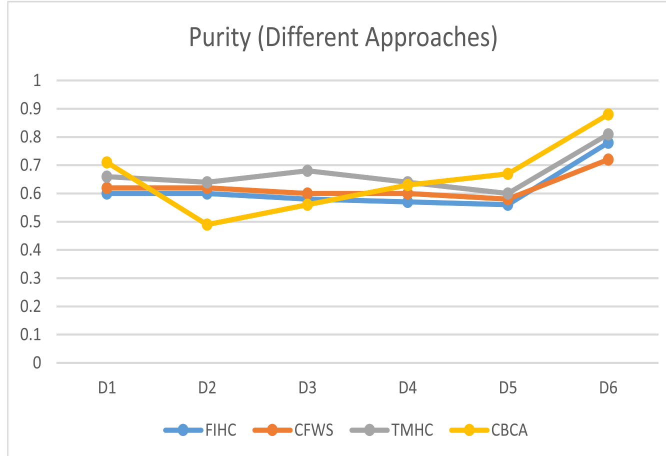

Fig. 7. Purity from different approaches on test datasets

REFERENCES

[1] Alessandro Campi and Stefania Ronchi. “The Role of Clustering in Search Computing”. In: *Database and Expert Systems Application, 2009. DEXA’09. 20th International Workshop on*. IEEE. 2009, pp. 432–436.
[2] Hung Chim and Xiaotie Deng. “Efficient phrase-based document similarity for clustering”. In: *Knowledge and Data Engineering, IEEE Transactions on* 20.9 (2008), pp. 1217–1229.
[3] Douglass R Cutting et al. “Scatter/gather: A cluster-based approach to browsing large document collections”. In: *Proceedings of the 15th annual international ACM SIGIR conference on Research and development in information retrieval*. ACM. 1992, pp. 318–329.
[4] Christiane Fellbaum. “ed. WordNet: an electronic lexical database”. In: *MIT Press, Cambridge MA* 1 (1998), p. 998.
[5] Rafael Ferreira et al. “A new sentence similarity assessment measure based on a three-layer sentence representation”. In: *Proceedings of the 2014 ACM symposium on Document engineering*. ACM. 2014, pp. 25–34.

[6] Benjamin CM Fung, Ke Wang, and Martin Ester. "Hierarchical Document Clustering using Frequent Itemsets." In: *SDM*. Vol. 3. SIAM. 2003, pp. 59–70.

[7] Khaled M Hammouda and Mohamed S Kamel. "Efficient phrase-based document indexing for web document clustering". In: *Knowledge and Data Engineering, IEEE Transactions on* 16.10 (2004), pp. 1279–1296.

[8] Marti A Hearst and Jan O Pedersen. "Reexamining the cluster hypothesis: scatter/gather on retrieval results". In: *Proceedings of the 19th annual international ACM SIGIR conference on Research and development in information retrieval*. ACM. 1996, pp. 76–84.

[9] Anil K Jain, M Narasimha Murty, and Patrick J Flynn. "Data clustering: a review". In: *ACM computing surveys (CSUR)* 31.3 (1999), pp. 264–323.

[10] Yanjun Li, Soon M Chung, and John D Holt. "Text document clustering based on frequent word meaning sequences". In: *Data & Knowledge Engineering* 64.1 (2008), pp. 381–404.

[11] Valentina Presutti, Francesco Draicchio, and Aldo Gangemi. "Knowledge extraction based on discourse representation theory and linguistic frames". In: *Knowledge Engineering and Knowledge Management*. Springer, 2012, pp. 114–129.

[12] Muhammad Rafi, M Shahid Shaikh, and Amir Farooq. "Document clustering based on topic maps". In: *arXiv preprint arXiv:1112.6219* (2011).

[13] Joseph Turian. *Using AlchemyAPI for Enterprise-Grade Text Analysis*. Tech. rep. Technical report, AlchemyAPI (August 2013), 2013.

[14] Yujing Wang et al. "Representing document as dependency graph for document clustering". In: *Proceedings of the 20th ACM international conference on Information and knowledge management*. ACM. 2011, pp. 2177–2180.

HAMSA: Highly Accelerated Multiple Sequence Aligner

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***Abstract*—For biologists, the existence of an efficient tool for multiple sequence alignment is essential. This work presents a new parallel aligner called *HAMSA*. *HAMSA* is a bioinformatics application designed for highly accelerated alignment of multiple sequences of proteins and DNA/RNA on a multi-core cluster system. The design of *HAMSA* is based on a combination of our new optimized algorithms proposed recently of vectorization, partitioning, and scheduling. It mainly operates on a distance vector instead of a distance matrix. It accomplishes similarity computations and generates the guide tree in a highly accelerated and accurate manner. *HAMSA* outperforms MSAProbs with 21.9-fold speedup, and ClustalW-MPI of 11-fold speedup. It can be considered as an essential tool for structure prediction, protein classification, motive finding and drug design studies.**

Keywords*—Bioinformatics; Multiple sequence alignment; parallel programming; Clusters; Multi-cores

I. Introduction

Although diverse methods for aligning multiple sequences have been designed, the accomplishment of alignment's vast computations in a highly accelerated and accurate manner is still a challenge [1]. Most multiple sequence alignment (MSA) tools utilize the progressive method because it is computationally efficient.

First, it calculates a distance matrix illustrating the divergence of each pair of sequences by a similarity score. *Second*, it uses a clustering method to create a guide tree constructed from pairwise sequence distances. *Third*, it builds up the final multiple alignments according to the order given by the guide tree. Some other MSA tools follow the iterative method. It makes an initial alignment of groups of sequences and then revises the alignment to achieve a more reasonable result.

The main contributions of this work are:

1) Designing a highly accelerated parallel tool for aligning multiple sequences on multicore clusters, called *HAMSA*, to align massive sequences rapid,
2) Implementing the proposed HAMSAtool using C++ with MPI and OpenMP on Bibliotheca Alexandrina cluster system, to testits quality,
3) Carrying out comprehensive tests on a variety of actual dataset sizes, to prove that our developed tool outperforms competitive existing tools.

The rest of this paper is organized as follows. *Section 2* summarizes briefly the fundamental tools used for aligning multiple sequences. *Section 3* explains the *HAMSA* proposed tool. *Section 4* presents results and comparisons with diagnosis. Finally, *Section 5* concludes the paper and suggests future work.

II. Related Work

In the last decade, various parallel MSA programs have been developed for reducing time consumption and handling big data. They differ in the parallel platform they use and the way they optimize computations and storage.

The ClustalW is the commonly used tool. Different versions of ClustalW have been developed for shared memory SGI Origin machine, multiprocessors, clusters, and GPUs [2]. Although ClustalW is the most highly cited aligner especially for huge number of sequences, its accuracy is not satisfied enough compered to T-Coffee and MSAProbs. And, it has a problem with long sequences.

The T-Coffee produced two parallel versions for clusters and clouds [3]. The MUSCLE's first parallel attempt was on SMP system then multiscale simulations for HPC cluster and Amazon AWS cloud have been presented [4]. Booth T-Coffee and MUSCLE achieves high accuracy and fast speed, but cannot handle large sized dataset.

The MAFFT have been parallelized using the POSIX Threads library for multi-core PCs [5]. MAFFT is very fast, nevertheless it has poor accuracy.

ParaAT is used to construct multiple protein-coding DNA alignments for a large number of homologs on multi-core machines [6]. It is very good tool for large-scale data analysis, however its speed is unsatisfied.

MSAProbs was optimized for modern multi-core CPUs by employing a multi-threaded design [7]. While MSAProbs is the best tool for demonstrating dramatically accurate alignment, it is very slow.

The parallel version of DIALIGN-TX was implemented using both OpenMP and MPI on a 28-cores heterogeneous cluster [8]. Its speed and accuracy are neutral.

The GPU-REMuSiC [9] was proposed to reduce the computation time of RE-MuSiC; the newest tool with the regular expression constraints. It has good speed but it cannot align long sequences.

III. *HAMSA* PROPOSED TOOL

The main goal of *HAMSA* is to provide biologists with an accelerated multiple sequence aligner with minimal space consumption. It consists of three different stages. The architecture showing the interaction between these three stages is presented in *Fig. (1)*. To illustrate how *HAMSA* works by going through its three stages, the processes of aligning a class of 35 HIV viruses is introduced as a case study.

The distance vector *DV* including the similarity scores between every pair for the input sequences, computed by Stage (1), is introduced in *Fig. (2)*. While, the phylogeny guide tree, constructed by Stage (2), is presented in *Fig. (3)*. And, the final alignment, resulted from Stage (3), is given in *Fig. (4)*. In the following, a detailed discussion of each stage is given.

A. Distance vector computation

Stage (1), the distance vector computation, takes as input a set of N sequences with average length L and produces a distance vector *DV* including all pairwise distances. Each DV cell contains the similarity score for pair of sequences, evaluated by using the *DistVect1* algorithm, proposed in [10].

DistVect1 is a highly efficient parallel vectorized algorithm for computing similarity distances using multicore clusters. It deduces an efficient approach of partitioning and scheduling computations that consumes less space and accelerates computations. *DistVect1* was mainly based on the accelerated vectorization algorithm *DistVect* proposed in [11].

DistVect has solved the problem that real biological applications face when the length of sequences is large and the memory requirement cannot be met.

Instead of seeing the process of distance calculations in a two-dimensional array (matrix), *DistVect* algorithm substitutes the matrix by three vectors only. One vector includes the anti-diagonal of the current computed score, and two other vectors save the two previously calculated anti-diagonals including Northern, Western and North-Western needed values. It reduces the space complexity from $O(L^2)$ to $O(L)$.

DistVect1 also presented a superior performance with very long sequences. For example, for aligning 200 sequences of length 30,488, ClustalW-MPI did not work, SSE2 [12] exhausted 22,949 sec., where *DistVect1* achieved it in 8,017 sec only. This accomplishment is due to its perfect vectorization and hybrid partitioning approaches.

B. Guide tree construction

Stage (2), the guide tree construction, takes the evaluated distance vector *DV* and computes a guide tree. It uses the optimized NJ phylogeny reconstruction algorithm (*NJVect*) presented [13]. *NJVect* is a massively parallel optimized algorithm that compensates matrices used in *NJ* [14] by vectors.

It achieves remarkable reductions in both time and space by eliminating redundant computations and breaking dependences, while preserving the accuracy. It outperforms ClustalW-MPI with 2.5-fold speedup.

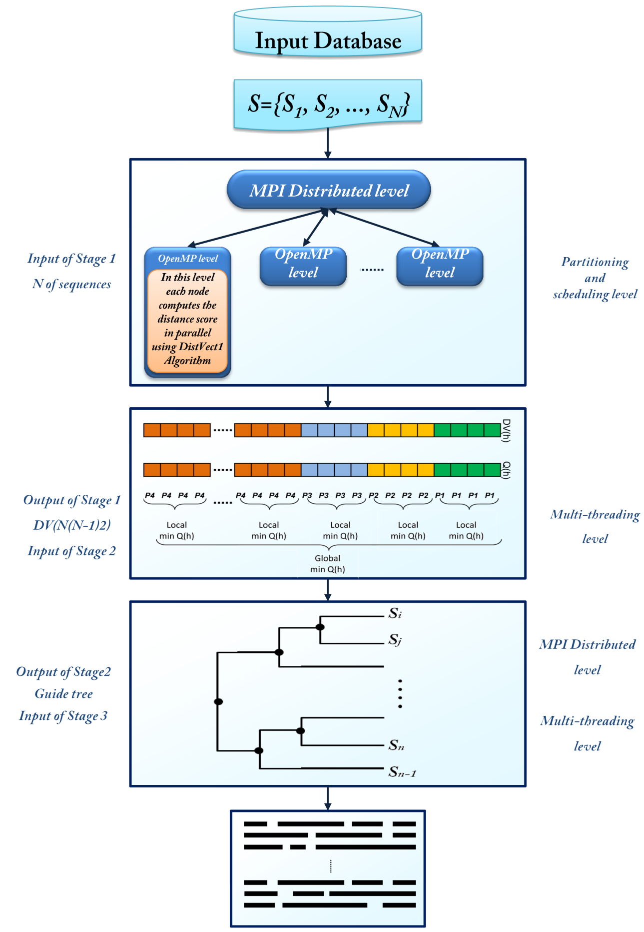

Fig. 1: Architecture of HAMSA.

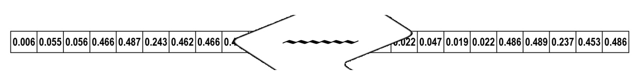

Fig. 2: Distance vector *DistVect1* of pairwise similarity distances.

C. Progressive alignment

Stage (3), the progressive alignment, uses the method provided by ClustalW-MPI for achieving progressive alignments. Its main objective is to distribute all external nodes (n) in the guide tree to be aligned in parallel. The efficiency obviously depends on the topology of the tree. For well-balanced guide tree, the ideal speedup is estimated as n/log n, where n is the number of nodes in the tree.

IV. EXPERIMENTAL RESULTS

HAMSA was implemented in C++, with MPI and OpenMP libraries. It accomplishes the alignment's vast computations in a highly accelerated and accurate manner. The experimental tests were conducted on Sun Microsystems cluster of 32 nodes, provided by LinkSCEEM-2 systems at Bibliotheca Alexandrina, Egypt. Each node contains two Intel Quad core Xeon 2.83 GHz processors (64 bit technology), with 8 GB RAM and 80 GB hard disk, a dual port in fin band (10 Gbps).

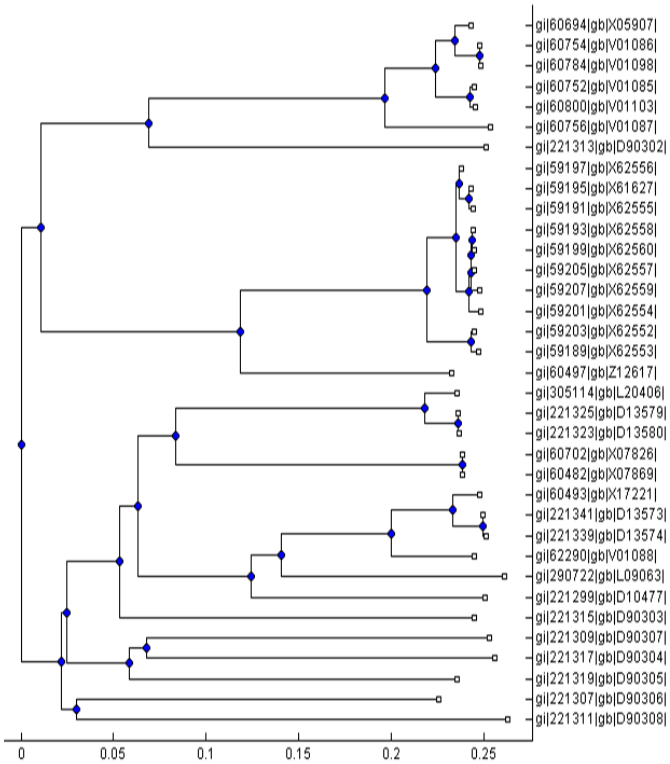

Fig. 3: Resulted phylogeny guide tree.

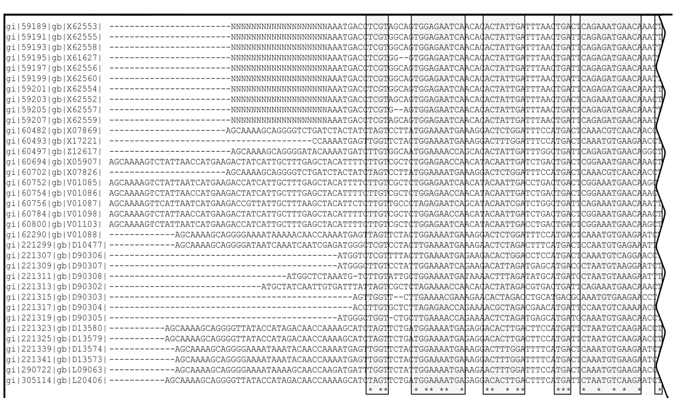

Fig. 4: Aligned sequences for 35 HIV viruses.

The experiments have been conducted using four protein real sequence datasets. These sequences have lengths ranging from 400 to 163,000 DNA residues, which made it possible to study the overall performance of solution against multiple different sizes.

The datasets consist of sequences selected from NCBI [15] and it was comprised of a subset of the Human Immunodeficiency Virus (HIV), the Coronaviridae family viruses (COR), the Hemagglutinin (Inuenza B virus (HA)), Herpesviridae (large family of DNA viruses (HRV)), and Plasmid (large family of DNA bacteria Enterobacteriaceae (ENA).

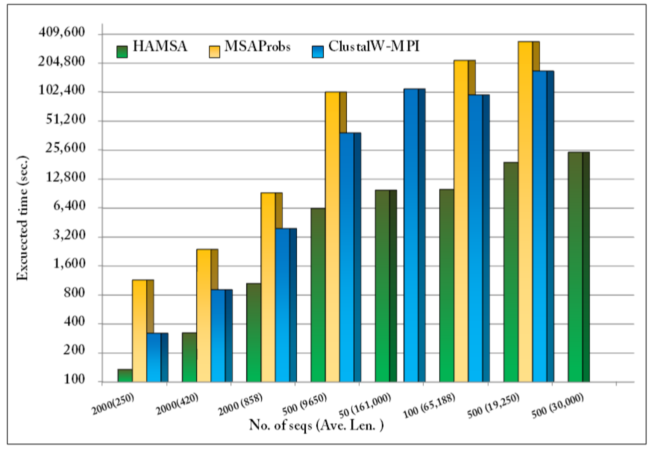

Fig. 5: Execution time measurements.

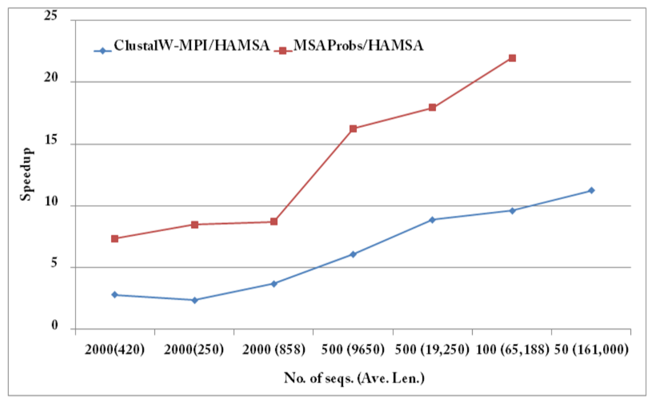

Fig. 6: Speed-up performance comparisons using 32 nodes.

The performance of *HAMSA* has been evaluated by using different metrics, such as: storage, execution time, speedup, efficiency, GCUPS, and occupancy. Its performance has been compared to ClustalW-MPI 0.13 [16], SSE2 [17], and MSAProb 3.0 [18]. *HAMSA* is able to handle the memory perfectly while computing distances between very long sequences; up to 163 k.

Fig. (5) shows that *HAMSA* has exhausted less execution time when aligning variant number of sequences (*N*) with different lengths (*L*) with respect to others. *Fig. (5)* shows that *HAMSA* has ability to achieve the maximum speedup with respect to the ClustalW-MPI and MSAProps for aligning the set 50 (161,000) and the set 100 (65,188), respectively.

Furthermore *HAMSA* can also achieve high GCUPs up to 13.835, while the highest values for ClustalW-MPI and MSAProps were 1.17 and 0.47, respectively, as shown in *Table (I)*. Furthermore, results recorded in *Table (II)* emphasize *HAMSA*'s high efficiency level against others. For CPUs occupancy, *HAMSA* reaches 100%.

TABLE I: *HAMSA* performance comparison in GCUPS

No. of seqs (Ave. Len.)	*HAMSA*	ClustalW-MPI	MSAProbs
500 (30,000)	9.7934	0.870756646	0
2000 (420)	3.2945	1.168593927	0.447014925
2000 (250)	2.83552	1.196421941	0.334377358
2000 (858)	4.1047	1.103413978	0.471208816
500 (9,650)	5.4928	0.901271638	0.338434997
500 (19,250)	7.249043	0.816977685	0.404296877
100 (65,188)	6.34465	0.661107638	0.288997449
50 (161,000)	13.835	0	0

TABLE II: Efficiency of *HAMSA* comparisons using 32 nodes

No. of seqs (Ave. Len.)	ClustalW-MPI	MSAProbs
2000 (420)	0.0881	0.2303125
2000 (250)	0.0740625	0.265
2000 (858)	0.11625	0.27221875
500 (9,650)	0.190453125	0.5071875
500 (19,250)	0.27728125	0.5603125
100 (65,188)	0.29990625	0.6860625
50 (161,000)	0.35146875	0

V. CONCLUSION AND FUTURE WORK

In this paper, *HAMSA* has been proposed for aligning multiple sequences efficiently by using a multi-core cluster system. *HAMSA* applies several optimization methods considering the memory usage and load balancing.

It provides a powerful improved storage handling capabilities with efficient improvement of the overall processing time. The beneficial of *HAMSA* is in relating the molecular structure to the underlying sequences as well as it can operate on local or online databases.

Experimental results show that *HAMSA* is an accelerated competitive MSA tool. *HAMSA* achieves speedup of 21.9 by comparing to MSAProbs and speedup of 11 by comparing to ClustalW-MPI.Its efficiency reaches 0.29, 0.086 and 0.092 over the ClustalW-MPI, SSE2 and MSAProbs, respectively.

Its performance varies from a low of 6.27 GCUPS to a high of 13.835 GCUPS as the lengths of the query sequences increase from 1,750 to 30,500, it also accomplishes 100

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REFERENCES

[1] F. F. M., N. M., and M. W., "An overview of multiple sequence alignment parallel tools," in *Proc. CSCCA '13*, Dubrovnik, Croatia, 2013, pp. 91–96.

[2] C.-L. Hunga, Y.-S. Linb, C.-Y. Linc, Y.-C. Chungb, and Y.-F. Chungc, "Cuda clustalw: An efficient parallel algorithm for progressive multiple sequence alignment on multi-gpus," *Journal of Computational Biology and Chemistry*, vol. 58, pp. 62–68, 2015.

[3] D. T. P., O. M., G. F., C. F., E. T., and N. C., "Cloud-Coffee: implementation of a parallel consistency-based multiple alignment algorithm in the T-Coffee package and its benchmarking on the Amazon Elastic-Cloud," *Bioinformatics*, vol. 26, no. 15, pp. 1903–1904, 2010.

[4] K. Rycerz, K. Poland, N. M., P. P., and C. E., "Comparison of cloud and local HPC approach for MUSCLE-based multiscale simulations," in *e-ScienceW '11, Maui, Hawaii*, 2011, pp. 81–88.

[5] K. K. and T. H., "Parallelization of the MAFFT multiple sequence alignment program," *Bioinformatics*, vol. 26, no. 15, pp. 1899–1900, 2010.

[6] Z. Z., J. X., J. W., H. Z., G. L., X. W., and L. Dai, "Paraat: A parallel tool for constructing multiple protein-coding dna alignments," *Biochemical and Biophysical Research Communications*, vol. 419, no. 4, pp. 779–781, 2012.

[7] L. Y., S. B., and D. L. Maskell, "MSAProbs: multiple sequence alignment based on pair hidden markov models and partition function posterior probabilities," *Bioinformatics*, vol. 26, no. 16, pp. 1958–1967, 2010.

[8] de Araujo Macedo E., M. A. de Melo A.C., P. G.H., and B. A., "Hybrid MPI/OPENMP strategy for biological multiple sequence alignment with DIALIGN-TX in heterogeneous multicore clusters," in *Proc. IPDPSW '11*, Alaska, USA, 2011, pp. 418–425.

[9] L. C.Y. and L. Y.S., "Efficient parallel algorithm for multiple sequence alignments with regular expression constraints on graphics processing units," *Int. J. Comput. Sci. Eng.*, vol. 9, no. 1/2, pp. 11–20, 2014.

[10] M. W. Al-Neama, N. Reda, and F. F. Ghaleb, "An improved distance matrix computation algorithm for multicore clusters," *BioMed Research International*, vol. Article ID 406178, http://dx.doi.org/10.1155/2014/406178, 2014.

[11] ——, "Fast vectorized distance matrix computation for multiple sequence alignment on multi-cores," *International Journal of Biomathematics*, vol. 8, no. 6, p. DOI: 10.1142/S1793524515500849, 2015.

[12] W. A., K. C. K., and S. B., "Multi threaded vectorized distance matrix computation on the Cell/BE and x86/SSE2 architectures," *Bioinformatics Advance*, vol. 26, no. 10, pp. 1368–1369, 2010.

[13] M. W. Al-Neama, N. M. Reda, and F. F. M. Ghaleb, "Accelerated guide trees construction for multiple sequence alignment," *International Journal of Advanced Research*, vol. 2, no. 4, pp. 14–22, 2014.

[14] N. M. Saitou N, "The neighbor-joining method: a new method for reconstructing phylogenetic trees," *Molecular Biology and Evolution*, vol. 4, no. 4, pp. 406–425, 1987.

[15] N. C. for Biotechnology Information (NCBI). (2011). [Online]. Available: http://www.ncbi.nlm.nih.gov/

[16] K.-B. Li. (2011) Clustalw-mpi 0.13 clustalw analysis using distributed and parallel computing. [Online]. Available: http://www.mybiosoftware.com/clustalw-mpi-0-13-clustalw-analysis-distributed-parallel-computing.html/

[17] W. A. and S. B. (2013, Jun.) Distance matrix comp on cell be and x86. [Online]. Available: http://www.mybiosoftware.com/clustalw-mpi-0-13-clustalw-analysis-distributed-parallel-computing.html/

[18] D. L. M. Yongchao Liu, Bertil Schmidt. (2010) Msaprobs: Multiple sequence alignment. [Online]. Available: https://sourceforge.net/projects/msaprobs/

Hashtag the Tweets: Experimental Evaluation of Semantic Relatedness Measures

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***Abstract*—On Twitter, hashtags are used to summarize topics of the tweet content and to help search tweets. However, hashtags are created in a free style and thus heterogeneous, increasing difficulty of their usage. Therefore, it is important to evaluate that if they really represent the content they are attached with? In this work, we perform detailed experiments to find answer for this question. In addition to this, we compare different semantic relatedness measures to find this similarity between hashtags and tweets. Experiments are performed using ten different measures and *Adapted Lesk* is found to be the best.**

***Keywords—component; formatting; style; styling; insert* (*key words*)**

I. Introduction

According to Danah M. Boyd & Nicole B. Ellison [1], a social network is a community, place or platform where people gather for similar cause or interest. Online social network users can interact with their social contacts as well as use number of services provided. For example, they can create profile, share posts, pictures, videos, status and use messaging [2, 3]. The huge numbers of online social network users share their feelings, thoughts, activities, knowledge, emotions and information on online network. Among popular online social networks, Facebook [4] and Twitter [5] are top. Facebook has leading position with registered user approximately 1 billion plus, 968 million active users per day, 844 million user's login on Facebook through mobile every day, and 4.75 billion posts are posted per day[1].

Twitter, another rapidly growing social networking site having registered users over 600 million, 316 million active users, 500 million tweets posted by users and 80% users use twitter's services on mobile phones [2]. The messages posted by a registered user on twitter are called tweets that can have maximum of 140 characters. User can post a lot of tweets at daily bases by using web interface, SMS or smart phones app. Unregistered users can only view and read tweets posted by different people [5]. The popularity of the twitter can be estimated by the fact that just after two years of its launching, company gained rapidly growth with 100 million tweets per quarter posted in 2008. By 2010, this amount reached to fifty million tweets per day [6] with company having 7000 registered applications [7]. This amount reached to phenomenal number of 600 million by year 2015[3].

A tweet is a short length message maximum 140 characters may consist of text, photos, web links and videos [15]. A Hashtag (like a label or metadata tag) is used by users on different social networking media and on other micro-blogging web sites that helps users to find messages, topics with a specific contents or theme. Users can create or use Hashtags by putting a "#" sign before a word or phrase without blanks and can be used in anywhere in tweet. Internationally, the hashtag became a practice of writing style for Twitter posts during the 2009–2010 Iranian election protests, as both English- and Persian-language hashtags became useful for Twitter users inside and outside Iran [36]. Beginning July 2, 2009, Twitter began to hyperlink all hashtags in tweets to Twitter search results for the hashtagged word. In 2010, Twitter introduced "Trending Topics" on the Twitter front page, displaying hashtags that are rapidly becoming popular[4]. Trending topics, the most discussed topics on Twitter at a given point in time, have been seen as an opportunity to generate traffic and revenue. Spammers post tweets containing typical words of a trending topic to attract clicks. This kind of spam can contribute to devalue real time search services [37].

[1] http://newsroom.fb.com/company-info/
[2] https://about.twitter.com/company
[3] http://www.internetlivestats.com/twitter-statistics/
[4] https://en.wikipedia.org/wiki/Hashtag#cite_note-13

Hashtags help searching relevant tweets from twitter. Spammers also use hashtags for their own purposes by attaching famous hashtags with spam information. In such cases tweet and their hashtags are both not related. This is the reason knowing relevancy of hashtags and tweets is not only important to search relevant information but also important to determine authenticity of the information. The purpose of this work is to find the relatedness of hashtags with tweets they are tagged to. There are many semantic relatedness measures proposed in the literature. The effectiveness of these measures for finding relatedness between hashtags and tweets is questionable. Hence, we plan to compare findings of these measures on our data collection.

To overcome such kind of spam tweets, there is a need to find if hashtags attached with a tweet are really relevant to it i.e. if the hashtags are describing actual content of tweet or an irrelevant hashtags has been attached to get some commercial benefits or because of some bad intentions. In this paper, we perform detailed experiments to find relatedness between a tweet and hashtags attached to it. We compare findings of several relatedness measures (already proposed in literature) for computing this relatedness between tweets and their hashtags. This task is challenged by many complex sub-tasks like segmentation of compound hashtags. For this particular sub-task, we use three methods and compare their results.

A. Research Questions

We focus on finding answers to following three research questions in this work:

- Do hashtags represent their tweets or not?
- Which is the best method for segregating compound hashtags?
- Which relatedness measure is good for estimating relatedness between tweets and hashtags?

I. CONTRIBUTIONS

- We develop a web application that helps to extract tweets on the bases of screen names (users) from twitter with the collaboration of twitter Rest API and save tweets into MySQL database.
- This application is capable to separate hashtags from tweets and save into selected database.
- This application uses three different methods to segment hashtags words like Regular expression, Google search engine and lexicon methods.
- We integrate a PHP library named PHP POS Tagging that helps us to get parts of speech from tweets like verbs, adverbs, nouns, adjectives and their sub types and save POS into database.
- This application uses web parsing technique to finds the similarity / semantics score b/w hashtag and tweets contents using different semantic relatedness / similarity algorithms like Adapted Extended Lesk, Lch, Jcn, Res etc. This application finds score using ten different algorithms.
- This application can help to find which types of POS are used in majority of tweets.
- This application can find mean (arithmetic) and also finds standard deviation from calculated result, from where we can predict about hashtags.

II. RELATED WORK

Hashtags have been used for several purposes in the work related to twitter. However, we discuss some important works in this section.

Piyush Bansal et al. [25] proposed a system that can analyze and segments the hashtags and return pages from Wikipedia for corresponding context of hashtag and its tweet text input to the system. Their proposed system has three components, segmentation seeder that generates a possible segmentation list by using variable length window technique. 2nd component deals with two tasks. First is the feature extraction from segmentation and 2nd is entity linking on segmentations. This component also finds the different scores like bigram score for accurate context matching, context score to find maximum contextual similarity with tweet's contents, capitalization score to find the information from hashtags written in capital words and relatedness score to find the relatedness between tweet context and hashtag segmentations. The 3rd component responsible for ranking of segmentation, produce a ranked list of segmentation along entity linking [25].

Ilknur Celik et al. [26] investigate the semantic relationships b/w entities from posts published by users on Twitter and develop a relation discovery framework that detects relations among entities of post. Their proposed system has two parts, first one is entity extraction and semantic enrichments, in which they detect entities and their semantic in reference of post, new or topic etc. the result in the form of graph that can be represented via triple G: = (R, E, Y), R & E are the resources and entities and   is a relation among resources and entities. The second step is relation discovery, in which detection of pairs of entities from graph that have a certain type of relationship in specific period of time. Relation b/w two entities e1, e2 can be defined via a tuple Rel (e1, e2, tstart, tend, w), in which tstart and tend specify the relation's validity and w is a weight of relation that's belongs to [0..1]. Highest score mean stronger relationship and lower score mean weaker relationship b/w entities.

Given the across the board of interpersonal organizations, research efforts to recover data utilizing tagging from informal communities correspondences have expanded. Specifically, in Twitter informal organization, hashtags are broadly used to define a common connection for occasions or subjects. While this is a typical practice frequently the hashtags openly presented by the user turn out to be effectively one-sided. Costa et al. [27] proposed to manage this inclination clustering so as to define semantic meta-hashtags comparable messages to enhance the classification. They utilized the client defined hashtags as the message class labels of Twitter and applied the meta-hashtag way to deal with help the execution of the message classification. The meta-hashtag methodology is tried in a Twitter-based dataset built by asking for open tweets to the Twitter API. The test results yielded by looking at a baseline model taking into account user's defined hashtags with the grouped meta-hashtag methodology demonstrate that the general classification is moved forward. It is presumed that by joining semantics in the meta-hashtag model can have sway in different applications, e.g. proposal frameworks, occasion identification or crowdsourcing. Their proposed system has two models, first baseline model that deals with user defined hashtags. In 2nd model (meta-hashtag model), they defined meta hashtags. They get a dataset using Twitter API and use support vector machine method for classification, and they use van Rijsbergen measure for classification. For evaluation their method they use Support Vector Machine to discover ideal optimal hyperplane b/w positive and negative cases [27]. Another related work is done by Planck et al. [28] and is worth reading.

Another interesting work on twitter relates to a very important task i.e. sentiment analysis. Sentiment analysis is a fast and efficient way to get knowledge about user's interest, felling towards brands, business etc. and there are many methods training sentiment classifier for Twitter dataset. Saif et al. [29] present a novel approach of adding semantics as extra feature into the preparation set for sentiment analyses, For each concept (e.g. iPhone) from tweets, they adds their semantic concept (e.g. "Apple item") as an extra component, and measure the relationship of the agent idea with negative/positive opinion. They apply this method on Twitter datasets for prediction of sentiment analysis. They apply this approach on three datasets, Stanford Twitter Sentiment Corpus (STS), Health Care Reform (HCR) and Obama-McCain Debate (OMD). They use open source APIs to extract entities from online textual data, then they use three different methods to incorporate semantic feature into Naïve Bayes classifier training. After this they replace all entities with their corresponding semantic concepts. After this they use Unigram, Part of Speech and Sentiment topics methods for features extraction. Their proposed sentient topic method has better results as compared to Unigram and Part of speech methods, for sentiment analyses.

Kywe et al. [30] research on hashtags by analysis a Twitter dataset having more than 150,000 users. They proposed a method based on filtering, the proposed method considers both client inclinations and tweet content in selecting hashtags to be suggested. They use collaborative filtering approach that referred as a "user to user" U2U filtering approach to rating targets both items and users to assign an item to a target user, another approach "item to item" based on correlation to assign an item to target user. They also recommend another approach based on measurements of similarity b/w items by comparing their features [30].

In paper [31], they proposed a novel method that recommends hashtags for Tweets written in English Language. They use a skip-gram model for distributed word representation that uses a log-linear classifier to predict words in a range. Feed forwarded neural network (FFNNs) model is used for language modeling and natural languages tasks (NLP). They created a neural network that uses a non-linear function on each of its layers. They create a network having different computational unit ranges from 300 to 1000 and dimension of each input & output layer is fixed by 300. A component name feature vector generation in which, They get a 300-dimensional component vector for each word of the tweet, Hashtags are also included, after getting dimensions they perform an average operations on different tweets word feature vectors to make a solitary tweet feature vector that's used as an input in FFNN. Dimension of this tweet feature vector is same as the dimension of a word feature vector. By averaging tweet feature vector is close to the tweet in semantically concept. They used Batch Gradient Decent algorithm and a Mean Squared Error MSE as objective function.

We have observed that many researchers have used the potential of hashtags on twitter. However, we have hardly seen any attempt (to the best of our knowledge) that focuses on their similarity with the actual content of tweets i.e. how much the hashtags represent the original tweet content? In next section, we describe our experiments to find answer for this question.

III. EXPERIMENTS

A. Data Collection

We integrate Twitter Rest API into our web application for extraction tweets from twitter web site. It allows getting recent 200 tweets & retweets for each user in single request and we can make 180 requests in a quarter of hour. It means we can extract 36000 tweets per quarter and 144000 tweets per hour. The Twitter Rest APIs[5] also gives facility of extract tweets on the base of user (screen names). There are following steps to extracts tweets.

- A user account is required at twitter web site that's initially step towards tweets extraction, here we have already registered user of twitter,
- we create an application on twitter to get user authentications information that helps a user to authorized himself, these are consumer key, secret key, access token and access secret token. Any user gets this confidential information by registering and creating an application on twitter,
- OAuth, an open standard that authorized a user by using above mentioned confidential information,
- Next step is to write a code to make connection with twitter using Rest API, for this purpose we use PHP web programming language and adobe Dreamweaver CS6 as editor. This application is host on a temporary domain for extracting tweets.

[5] https://dev.twitter.com/rest/public

We extract around above 15000 tweets as a sample data set. We extracts the General Tweets posted in different domains, instead of specific domain or community i.e. Politicians or businessman. These are mixed tweets that contain Hashtags having English words, different terminologies, local language words, symbols and many more.

B. Data Processing and Storage

Once the data collection has been prepared, we do following steps:

- Remove duplicate tweets,
- Remove digits from hashtags,
- Remove tweets having words other than English language,
- Remove tweets with hashtags including abbreviations or acronyms,

After applying this processing, we are left with total 8001 tweets to work on. We use MySQL database management system for storage of these processed tweets. We store tweets, separated hashtags, segmented hashtags words. The database schema is shown in figure 1.

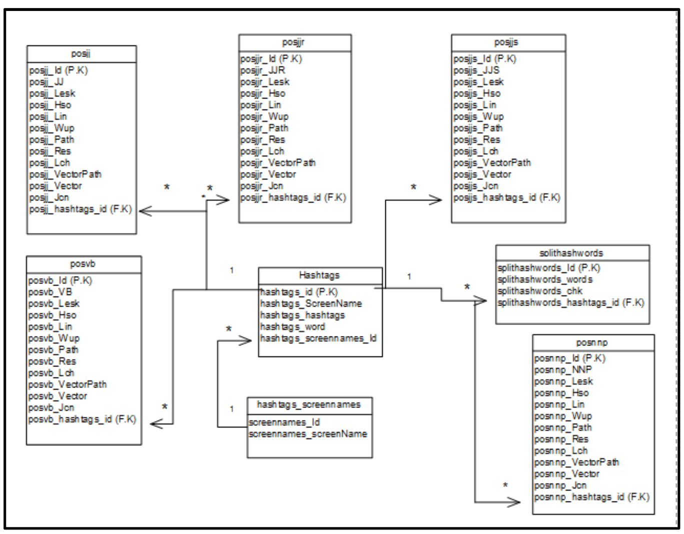

Figure 1: Database Schema

C. Segregating Compound Hashtags

As discussed earlier, the task of computing relatedness between tweets and their hashtags involves some sub-tasks. One of the sub-tasks is to extract individual words from a compound hashtag. For example, if we find a hashtag #savetheworld then we need to identify all three individual words present in this hashtag i.e. 'save', 'the', and 'world'. It is very important to identify correct words from hashtags because performance of major task i.e. finding relatedness between hashtags and tweets depends on this correct identification.

IV. SEGREGATING COMPUND HASHTAGS

This sub-task of extracting individual words from compound hashtags is performed in two steps. First step in this regards is to extract hashtags from tweets themselves. For this purpose, we write a simple code which separates hashtags from tweets with 100 percent accuracy. The second step is separation of compound Hashtags. A careful analysis of hashtags reveals that most of the people use capitalized and well defined words to make hashtags. However, some use hashtags containing words in lower case letters while many others combine lowercase and uppercase letters for this purpose. We categorized Hashtags into the followings:

- Uppercase words
- Lowercase words
- Capitalization words
- Mixed words

It is very easy to identify words in a hashtag written in capitalization form (i.e. #SaveTheWorld) while it becomes difficult for rest of the forms. Therefore, we decide to experiment with four different methods to identify individual words in hashtags and extract them. Each method is described in detail in following sub-sections.

A. Extracting Individual Words Using Regular Expression

This method based on regular expression that uses along coding and this is the most successful method because majority of people used capitalization case to make compound Hashtags. This method can segment hashtags that contains the following type of words

- English words
- English names
- English movies names
- Roman Urdu names
- Lowercase single words
- Uppercase words
- Capitalization words
- Others languages words

We use the pooling method for finding accuracy of this method by using a pool of 1000 hashtags. The accuracy of this method is 911/1000 = 91.1%.

B. Extracting Individual Words Using Google Search Engine

In this we method, we use Google search engine to separate Hashtags. We use this method based on query technique, in which we make a unique query for each Hashtags to Google search engine. This method can segment hashtags that contains the following type of words

- English words
- English names

- English movies names
- Roman Urdu names
- Lowercase single words
- Uppercase words
- Capitalization words
- Others languages words

We find accuracy of this method by testing and analyzing the sample of first 1000 hashtag that is 925 / 1000 = 92.5%.

C. Extracting Individual Words Using combination of Regular Expression &Google Search Engine

It is a hybrid method which combines regular expression method as well as Google search engine method. First we use Regular Expression. While segmenting hashtags it checks every segmented word from lexicon WordNet database that's we already stored in our local schema, if match found that word is stored in another "splithashwords" table with flag value 0, if match not found then it also store relevant word into same table but with a flag value 2. After finishing compilation of regular expression, second method Google Search Engine start working, in which it select all words from table by querying and try to segment words with flag value 2. Successful segmented words again save into same table with flag value 0 and compound word with flag value 2 is deleted at the last of searching completed otherwise not. Its accuracy rate is much higher as compared to first two methods. We find accuracy of this method by testing and analyzing the sample of first 1000 hashtag that is 978 / 1000 = 97.8%.

D. Extracting Individual Words Using Lexicon Method

This method is based on coding as well as lexicon database to segment Hashtags. It is effective in segmentation of compound hashtags written either in uppercase, capitalization, mixed and specially in lowercase letters but it is not easy to implement because it makes a lot of queries to database to find possible matches and processing, after finding possible matches then it makes permutations of all retrieved matches, after permutations it again find the accurate permutation that will takes a lot of time and involve a lot of processing, time and processing cost of this method is depend on hardware. It takes much time to segment a Hashtag consisting of two words like **#blindlycartouche,** it is consisting of two words blindly and cartouche. It successfully segment the above mentioned hashtag but take a lot of time. The compound hashtags may consists of different no. of words and each word has different length of characters. This method fails if hashtags contain words are not present in lexicon WordNet database. We are unable to implement this method due to a lot of time consumption, here's some calculations that describes how's this method is costly and not possible to implement. We choose random hashtags containing two to five words and each word having length from two to five characters. We assume that all hashtags belong to lexicon database and have length from two to four words, the cost of lexicon method cost shown below in different tables (table 5 onwards). We find accuracy of this method by testing and analyzing the sample of first 1000 hashtag that is 512 / 1000 = 51.2%.

E. Extraction of Parts of Speech (POS) from Tweets

At this step we extract part of speech (POS) from Tweets for the purpose of finding semantic relatedness between segmented hashtags and contents of tweets that consists of (nouns, adverbs, adjectives, verbs and their sub forms). To perform this task we used a PHP library named "PHP Tagger", which is used to extract POS from any given sentence. We use it for extraction of POS from tweets by passing tweets to Tagger function. We extract nouns, verbs, adverbs, adjectives and respective sub forms. We extract POS and save into MySQL database. Following types of POS tags are considered for match with hashtags.

Table 1: Part of Speech

Sr. #	POS	Type
1	NN	Noun, singular or mass base form
2	NNS	Noun, plural
3	NNP	Proper noun, singular
4	NNPS	Proper noun, plural
5	RB	Adverb base form
6	RBR	Adverb, comparative
7	RBS	Adverb, superlative
8	JJ	Adjective base form
9	JJR	Adjective, comparative
10	JJS	Adjective, superlative
11	VB	Verb, base form
12	VBD	Verb, past tense
13	VBG	Verb, gerund or present participle
14	VBN	Verb, past participle
15	VBP	Verb, non-3rd person singular present
16	VBZ	Verb, 3rd person singular present

Following table describes the processed data collection statistics.

Table 2: Data Size after Processing

Screen Names	196
Hashtags	8001

Segmented Words (hashtags)	15019
Adjectives	7121
Nouns	61972
Verbs	14489

V. MATCHING TWEETS AND THEIR HASHTAGS

Now our raw material is ready to calculate similarity / relatedness among segmented Hashtags and POS of tweets. For this purpose we use a web interface based on WordNet similarity package that is powered by Ted Pedersen and Jason Michelizzi. This web interface provides a way to find semantic relatedness / similarity score b/w two words. This web portal calculates semantic score by using ten different algorithms. We find the score of all segmented Hashtags and their relevant POS by using all algorithms and save it into database for further calculation / use. The list of algorithm that calculate semantic relatedness is given below

I. Adapted Extended Lesk
II. Hirst & St-Onge (HSO)
III. Lin
IV. Wu & Palmer (wup)
V. Path Length
VI. Resnik (Res)
VII. Leacock &Chodorow (Lch)
VIII. Gloss Vectors (pair-wise)
IX. Gloss Vectors (Vector)
X. Jiang & Conrath (Jcn)

A. Normalization

Algorithms used to match tweets with their hashtags use different scoring mechanisms and hence results computed by using these algorithms cannot be compared unless brought on same scale. We use following formula for normalizing results:

Normalized values Wi = Xi – minimum (X) / (maximum (X) – minimum (X))

Here,

- Wi is the normalized value.
- Xi is a value belongs to variable X.
- Minimum(X) is the smallest value from variable X.
- Maximum(X) is the extreme value from variable X.

As a result of normalization, results of all algorithms are brought on 0 and 1 scale and hence are comparable. These normalized values are then averaged (arithmetic mean) for each algorithm.

B. Final Results

After normalization of semantic relatedness scores and averaging them, the final results for different algorithms are given below:

Table 3: Algorithm wise results

Sr. #	Algorithm	Results
1	Adapted Extended Lesk	0.701
2	Hirst & St-Onge (HSO)	0.338
3	Lin	0.089
4	Wu & Palmer (wup)	0.232
5	Path Length	0.085
6	Resnik (Res)	0.392
7	Leacock & Chodorow (Lch)	0.456
8	Gloss Vectors (pair-wise)	0.038
9	Gloss Vectors	0.117
10	Jiang & Conrath (Jcn)	0.324

VI. GROUND TRUTH PREPARATIONS

One of the objectives of this work is to evaluate and compare different semantic relatedness measures. For this purpose, we need to have gold standard so that results of these relatedness measures can be compared with it. The objective is to find some overall coherence between results of automatic matching using algorithms and manual match. It will confirm the findings of matching algorithms. For this purpose we choose four educated persons from different fields of life having good experience of using social networking sites and very well know about twitter and tweets. They evaluate our dataset (Tweets & Hashtags) carefully and answered in from of two options yes or no for each tweet and hashtag to tell the relevancy b/w hashtags and tweets. They evaluate 11000 plus tweets and answered with very responsibility. To find the agreements ration between annotators, we decide to use Fleiss' kappa. Fleiss' kappa (named after Joseph L. Fleiss) is a statistical measure for assessing the reliability of agreement between a fixed numbers of raters when assigning categorical ratings to a number of items or classifying items. This contrasts with other kappa such as Cohen's kappa, which only work when assessing the agreement between two raters. The measure calculates the degree of agreement in classification over that which would be expected by chance. There is no generally agreed-upon measure of significance, although guidelines have been given. Fleiss' kappa can be used only with binary or nominal-scale ratings. No version is available for ordered-categorical ratings [35]. At next step we use Fleiss' kappa to find the agreement among four evaluations. The results are given below in table 4.

Table 4: Fleiss Kappa Results

FILENAME	Tweets.csv
File size	89616 bytes
n-coders	4
n-cases	9956
n-decisions	39824

Average pair-wise percent agreement	78.22%
FK observed agreement	0.78

Another major reason why we need to evaluate our data by users is that numerous users don't follow the netiquette. For example, they tag the irrelevant word with Hash (#) which creates the problem to specify hashtag for any Generic Field. Due to lack of standards for inputting hashtag peoples add any kind of hashtags to represent tweets. Even English people (our concerned data set) create hashtags that have no meanings in any sense but they are written followed by # sign i.e.

- #TÃ¼mTwitterBuTaglaMutlu
- #aÅŸk
- #Hamburg!!!ðŸ™ˆðŸ˜ ðŸ˜ŽðŸ‡©ðŸ‡ªâ ¤ï
- #politicalprisoners
- #ARR
- #HBDPM
- #SOUTHCOM

Above mentioned hashtags and many more are written by users upon their desires, they are not following any standard or rules. Peoples use special characters, pure in upper or lower case and mixed case, digits, roman words etc. Our web application cannot fulfill judgment on all types of hashtags, so we decide to perform user evaluation.

VII. CONCLUSIONS AND FUTURE WORK

On the basis of our experimental results and user evaluation, we conclude that hashtags mostly represent the tweets they are attached with. As far as correctness of semantic algorithms is concerned, our findings are given below:

- Adapted Extended Lesk is found to be the best at finding the relatedness between hashtags and tweets, the measurements of this algorithm is **0.701,**
- Lch measurement is **0.456**
- Resnik (Res) measurement is **0.392**
- Hirst & St-Onge (HSO) measurement is **0.338**
- Jiang & Conrath (Jcn)measurement is **0.324**
- Wu & Palmer (wup) measurement is **0.232**

We keep following points as part of our future work:

- Integrate other twitter APIs specially search API to get a large no. of screen names as well as tweets.
- Write a code to search and save screen names into database on the bases of any given keywords
- Write a code to deal automatically with data rate limit restriction by twitter to save time and get better results.
- Upgrade web application to deal with every kind of compound hashtags written in lowercase and uppercase.
- Upgrade web application to deal with roman hashtags as well as hashtags written in other than English language.
- Improve lexicon method to get better results in every aspect like speed, accuracy and time.
- Improve regular expression method that also deals hashtags other than written in capitalization.
- Improve Google Search Engine Method to finds context / meaning of abbreviation and acronyms.
- We want to restructure our database schema for better performance.
- Improve our segmentation methods of hashtags and our web application to handle
  - Hashtags including abbreviations, acronyms.
  - Hashtags having words or symbols other than English language.
  - Hashtags having pure lowers case i.e. not using capitalization.
  - Hashtags having mixed abbreviations, acronyms & English Words.
  - Hashtags having mixed English words and Roman Urdu words.
  - Hashtags with roman Urdu (Pakistanis & Indians writes their Urdu & Hindi in English)

REFERENCES

[1] Boyd, danah; Ellison, Nicole (2008). "Social Network Sites: Definition, History, and Scholarship". Journal of Computer-Mediated Communication 13: 210–230.doi:10.1111/j.1083-6101.2007.00393.x
[2] Journal of Computer-Mediated Communication Volume 13, Issue 1, pages 210–230, October 2007
[3] https://en.wikipedia.org/wiki/Social_networking_service
[4] http://newsroom.fb.com/company-info/
[5] https://about.twitter.com/company
[6] Beaumont, Claudine (February 23, 2010). "Twitter Users Send 50 Million Tweets Per Day – Almost 600 Tweets Are Sent Every Second Through the Microblogging Site, According to Its Own Metrics". The Daily Telegraph (London). Retrieved February 7,2011
[7] Staff writer (March 4, 2010). "Twitter Registers 1,500 Per Cent Growth in Users". New Statesman. Retrieved February 7, 2011.
[8] Garrett, Sean (June 18, 2010). "Big Goals, Big Game, Big Records". Twitter Blog (blogof Twitter). Retrieved February 7, 2011.
[9] "Twitter Blog: #numbers". Blog.twitter.com. March 14, 2011. Retrieved January 20,2012.
[10] Kazeniac, Andy (February 9, 2009). "Social Networks: Facebook Takes Over Top Spot, Twitter Climbs". Compete Pulse (blog of compete.com). Retrieved February 7, 2011.
[11] Weil, Kevin. (VP of Product for Revenue and former big data engineer, Twitter Inc.). "Measuring Tweets." Twitter Official Blog. February 22, 2010.
[12] Krikorian, Raffi. (VP, Platform Engineering, Twitter Inc.). "New Tweets per second record, and how!" Twitter Official Blog. August 16, 2013.
[13] Official Blog. June 30, 2011.
[14] "Twitter turns six." Twitter Official Blog. March 21, 2012.social-media-from-trend-to-obsession-infographic/142323
[15] https://support.twitter.com/articles/13920
[16] Using Twitter with Your Phone". Twitter Support. Retrieved June 1, 2010. We currently support 2-way (sending and receiving) Twitter SMS via short codes and one-way (sending only) via long codes.
[17] Logical Argument on CrystalTower, showing that accessing Twitter through SMS may incur phone service provider fees
[18] https://en.wikipedia.org/wiki/Hashtag
[19] Michael Schneider (Apr 21, 2011). "New to Your TV Screen: Twitter Hashtags". TV Guide.

[20] Todd Wasserman (Dec 3, 2012). "McDonald's Releases First TV Ad With Twitter Hashtag
[21] Heather, Kelly (12 February 2013). "Twitter and Amex let you pay with a hashtag".CNN. Retrieved 2013-11-25.
[22] Akwagyiram, Alexis (17 May 2012). "Are Twitter and Facebook changing the way we complain?". BBC News. Retrieved 2012-06-12.
[23] Maynard (2014). "Who cares about sarcastic tweets? Investigating the impact of sarcasm on sentiment analysis". Proceedings of the Conference on Language Resources and Evaluation.
[24] Anna MehlerPaperny (Apr 13, 2011). "Jack Layton's debatable 'hashtag' #fail". The Globe and Mail.
[25] Towards Deep Semantic Analysis of Hashtags by Piyush Bansal, RomilBansal and Vasudeva Varma International Institute of Information Technology Hyderabad, Telangana, India (http://link.springer.com/chapter/10.1007%2F978-3-319-16354-3_50)
[26] Learning Semantic Relationships between Entities in Twitter by IlknurCelik, Fabian Abel, and Geert-Jan Houben (http://dl.acm.org/citation.cfm?id=2027790)
[27] Joana Costa, Catarina Silva, MárioAntunes and Bernardete Ribeiro, Defining Semantic Meta-hashtags for Twitter Classification (http://link.springer.com/chapter/10.1007%2F978-3-642-37213-1_24)
[28] Max Planck, Isis LymanPollard,Charles Brock, Alex George , Initial Indicators of Topic Success in Twitter Using topology entropy to predict the success of twitter hashtags (http://www.computer.org/csdl/proceedings/nsw/2013/0436/00/06609214.pdf)
[29] Hassan Saif, Yulan He, and Harith Alani, Semantic Sentiment Analysis of Twitter by (http://iswc2012.semanticweb.org/sites/default/files/76490497.pdf)
[30] Su Mon Kywe, Tuan-Anh Hoang, Ee-Peng Lim and Feida Zhu, On Recommending Hashtags in Twitter Networks (http://link.springer.com/chapter/10.1007%2F978-3-642-35386-4_25#page-1)
[31] Tomar, Aparna, et al. "Towards Twitter hashtag recommendation using distributed word representations and a deep feed forward neural network."*Advances in Computing, Communications and Informatics (ICACCI, 2014 International Conference on*. IEEE, 2014.
[32] https://en.wikipedia.org/wiki/Data_collection
[33] https://en.wikipedia.org/wiki/Arithmetic_mean
[34] Law, E., Roto, V., Hassenzahl, M., Vermeeren, A., Kort, J.: Understanding, Scoping and Defining User Experience: A Survey Approach. In Proceedings of Human Factors in Computing Systems conference, CHI'09. 4–9 April 2009, Boston, MA, USA (2009)
[35] https://en.wikipedia.org/wiki/Fleiss%27_kappa
[36] "The story of the hashtag began with Iranians". Deutsche Welle Persian. 2009. Retrieved March 12, 2015
[37] Benevenuto, Fabricio, et al. "Detecting spammers on twitter." Collaboration, electronic messaging, anti-abuse and spam conference (CEAS). Vol. 6. 2010

Table 5: Cost using two words in Hashtags

Sr. #	Words	Each word's Length	Total Queries	Possible matches	Total permutations	Time in Milliseconds	Successful / unsuccessful
1	BkBw	2	147478	6	21	92.384	Yes
2	DocDoe	3	147479	8	36	91.738	Yes
3	HereHero	4	147480	10	55	96.476	Yes
4	AbaseWidth	5	147481	22	253	94.584	Yes
Total	4	14	589912	46	365	375.182	
Average	1	3.5	147478	11.5	91.25	93.795	

Table 6: Cost using three words in hashtags

Sr. #	Words	Each word's Length	Total Queries	Possible matches	Total permutations	Time in Milliseconds	Successful / unsuccessful
1	BkBwKm	2	147478	8	128	90.499	Yes
2	DocDoeDie	3	147479	13	468	88.253	Yes
3	HereHeroBraw	4	147480	20	1760	87.773	Yes
4	AbaseWidthStrap	5	147481	29	4524	88.226	Yes
Total	4	14	589912	70	6950	354.751	
Average	1	3.5	147478	14	1737.5	88.687	

Table 7: Cost using four words in hashtags

Sr. #	Words	Each word's Length	Total Queries	Possible matches	Total permutations	Time in Milliseconds	Successful / unsuccessful
1	BkBwKmZu	2	147478	11	858	87.901	Yes

2	DocDoeDiePud	3	147479	17	4199	89.533	Yes
3	HereHeroBrawGlee	4	147480	26	21203	90.912	Yes
4	AbaseWidthStrapWorth	5	147481	35	67340	93.754	Yes
Total	4	14	589912	89	93600	362.1	
Average	1	3.5	147478	22.25	23400	90.525	

Table 8: Average Cost of lexicon method

Sr. #	**Words in Hashtags**	**Total Queries**	**Possible matches**	**Total permutations**	**Time in Milliseconds**
1	Two	147478	11.5	91.25	93.795
2	Three	147479	14	1737.5	88.687
3	Four	147480	22.25	23400	90.525
Total	3	589912	47.75	25228.75	273.007
Average	1	147478	15.916	8409.583	91.0

Table 9: Cost of overall dataset using lexicon method

Sr. #	**Words in Hashtags**	**Total Queries**	**Possible matches**	**Total permutations**	**Time in Milliseconds**
1	1	147478	15.916	8409.583	91.0
	8001	8001*147478	8001*15.916	8001*8409.583	8001*91
	Average Total Cost	**1179971478**	**127343.916**	**67285073.583**	**728091**

Knowledge-based Approach for Event Extraction from Arabic Tweets

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***Abstract*—Tweets provide a continuous update on current events. However, Tweets are short, personalized and noisy, thus raises more challenges for event extraction and representation. Extracting events out of Arabic tweets is a new research domain where few examples – if any – of previous work can be found. This paper describes a knowledge-based approach for fostering event extraction out of Arabic tweets. The approach uses an unsupervised rule-based technique for event extraction and provides a named entity disambiguation of event related entities (i.e. person, organization, and location). Extracted events and their related entities are populated to the event knowledge base where tagged tweets' entities are linked to their corresponding entities represented in the knowledge base. Proposed approach was evaluated on a dataset of 1K Arabic tweets covering different types of events (i.e. instant events and interval events). Results show that the approach has an accuracy of, 75.9% for event trigger extraction, 87.5% for event time extraction, and 97.7% for event type identification.**

Keywords*—Event Extraction; Knowledge base; Entity linking; Named entity disambiguation; Arabic NLP.

I. Introduction

Social media sites such as Facebook and Twitter provide the most updated events leveraging the social generated content. Hundreds of millions of tweets are provided every day covering a variety of events and news. However, extracting structured information about events from these tweets holds a great promise especially when it comes to visualize events in more appealing way according to users' interests. Nevertheless, linking entity mentions in tweets with their events to their corresponding entities in the knowledge base fosters many research fields such as knowledge base population, questions answering, and information integration.

Many of previous research on event extraction [1]–[4] have focused on document level extraction such as News articles and Blogs, whereas few examples can be found on event extraction from noisy text such as tweets [5]–[10]. However, research targeting event extraction out of Arabic text is limited [11]–[13] and to the best of our knowledge there is only one concurent research reported on event extraction out of Arabic tweets [14].

In general, extracting information from noisy text such as social media posts is challenging. Such posts are disorganized and require automated approaches of information extraction and categorizing. For instance, tweets are short and self-contained which make them lack useful discourse information such as contextual information. According to [10], Twitter holds a set of challenges when it comes to event extractions such as: (a) tweets are personalized and mainly hold information about owner daily activities that of interest for their close social network only. (b) Tweets are short and self-contained and usually lack information about their context which causes NLP tools to perform poorly. On the other hand, such challenges hold great promises to enhance and adapt state-of-the-art NLP tools accordingly. (c) Twitter users informally contribute to a variety of topics and domains thus complex to categorize.

With the advances of Semantic Web and the so-called Web 3.0 folksonomy-based social environments, interoperability of knowledge management is a key challenge where semantics play an important role in facing it [15]. However, this cannot be achieved without bridging Web data with knowledge bases through linking named entity mentions appearing in Web material with their corresponding entities in a knowledge base [16].

Entity linking plays a major role when it comes to populate information to the knowledge base, or integrating extracted information from the Web. Adding newly extracted information to the knowledge base requires an entity linking step between entity mentions (in the text) and their corresponding entities in the knowledge base [17], [18]. However, non of the events extraction related work has focused on the events entities disambiguation or linking.

In this research, an unsupervised approach for event extraction out of Arabic tweets is discussed. The approach tags the event expression and the related entities and link them to the knowledge base entities and events. To the best of our knowledge there is no research that links events entity mentions to the Linked Open Data (LOD) as part of the event extraction process. This research links events' entity mentions (i.e. Person, Location, and Organization) to their corresponding entities in Wikipedia or DBpedia. This process is handled through an ontology based knowledge base that has been designed to represent event entities and link them to LOD. Moreover, newly extracted events (not available in the knowledge base) are populated to the knowledge base. Events represented in the knowledge base are used to provide services such as a calendar, or a time-line of events.

The rest of this paper is organized as follows: Section 2 sheds the light on previous and related work for event extraction out of Arabic text in general and Arabic tweets in particular. Section 3 discusses the proposed approach and explains the method of event extraction and representation. Section 4 reports the approach evaluation procedure and results. Section 5 discusses the evaluation results. Finally, Section 6 concludes this work and provides plans for future work.

II. Related Work

Recently, the problem of event extraction in general and event extraction from noisy text in particular has gained the researchers interest. However, few examples can be found on Arabic tweets. Related work for event extraction can be categorized according to the used corpora into: (a) document-level event extraction, and (b) sentence-level event extraction.

A. Document-Level Event Extraction

Allan et al. [1] propose an approach that is able to extract events out of news articles. The approach employs a feature extraction algorithm that processes each news article sequentially to build a query representation for each one. Then uses a comparison algorithm to determine the article that contains events and add it to their database. The approach was tested on 15,863 news articles from the period of July-1994 to June-1995. Results showed that the approach was able to detect events with F-measure = 0.49.

Ahn [19] proposes an approach that uses a number of machine learning techniques in order to extract events from ACE corpus. The process of extracting the events was split into a four main sub tasks: (a) Anchor identification, (b) Arguments identification, (c) Attribute assignment and (d) Event co-reference. The approach was trained using a set of features such as: lexical features, WordNet features and Dependency features. Results achieved was with F-measure = 0.601 for the overall subtasks.

Chambers and Jurafsky [4] propose an unsupervised approach that learns and extracts a template scheme structure automatically from text and produces a set of linked events such as war events. The approach was evaluated using the MUC-4 terrorism dataset [20]. Results showed that the approach was able to extract template structure very similar to the annotated gold structures (F-measure = 0.40).

On the other hand, some examples can be reported for event extraction out of Arabic documents. For instance, Abuleil [11] uses a lexicon-based approach to extract event mentions out of Arabic articles. Out of 300 articles the approach was able to detect 439 events out of 467 events.

Saleh et al. [12] propose a machine learning method to extract Arabic temporal and numerical events. They created an Arabic Treebank and used it to tag temporal expressions in Arabic text.

Aliane et al. [13] use an unsupervised approach for text segmentation and a rule-based approach to extract events' expressions and their locations. The approach was tested on a corpus of 30 articles crawled from the web, and was able to extract 168 verbal events out of 268.

B. Sentence-level Event Extraction

Lin et al. [5] propose an approach that deals with popular event tracking (PET) in online websites by focusing on the interaction between textual structure and social networks. A statistical approach that models the popularity of events over time period was evaluated on two different datasets (i.e., DBLP and twitter) and showed a good enhancement over similar approaches that used the same datasets.

Ritter et al. [10] present TwiCal for extracting events out of tweets. For a given tweet, their system was able to extract named entities with event phrases, events dates and events type. Each tweet was part-of-speach (POS) tagged, then named entities and events phrases were extracted and finally the events were categorized into their correct types and visualized as a calendar. TwiCal used a supervised approach by annotating a corpus of 1000 tweets that was used to train a conditional random field classifier to extract events phrases. The TimeBank [2] annotation guidelines were used to annotate their dataset. TimeBank is a corpus that was annotated to indicate events, times, and temporal relations. TimeBank contains the most accurate annotated data of events that existed in the year of 2003. Contextual, dictionary, orthographic and POS features were extracted out of the dataset and used to train the supervised approach. The approach results were compared with a system that did not make use of POS feature, and with another system that was trained on the Timebank corpus and used the same set of features. The F-Score measure for their system was 0.64 compared with a 0.57 to the system that did not use the POS feature and 0.15 to the approach that used the TimeBank corpus.

Becker et al. [6] analyze a stream of tweets of whether a tweet contains an event or not. The approach proposes an online framework that consists of two main tasks: filtering and clustering. By using an incremental clustering algorithm they train a classifier that predicts which cluster should be mapped to a tweet at any point of time. The approach was evaluated using 2,600,000 tweets, which were crawled during February-2010 and compared to the manually annotated 300 clusters test set. Moreover, the approach was compared to a traditional classifier - i.e. Naïve Bayes classifier - where the F-measure for the Naïve Bayes was 0.70 and 0.873 for the streaming approach.

Another work was done by a group of researchers at Yahoo labs, Popescu et al. [9] propose what they called an 'aboutness' system that relies on a huge dictionary of millions of phrases and lexical variants. Using a computational equation, the approach extracts the main events with potential entities that might exists in the tweet. The approach was evaluated on a dataset that consists of 5,040 tweets.The dataset was manually annotated into two main types of tweets, events (2249 tweets)and non-events (2791 tweets), Two main approaches were developed

Example 1:
In Arabic: "اعلان فيلم اللص الظريف دريد لحام ونيللي في سينما المتروبول في بيروت 16 كانون الاول 2015"

Buckwalter Transliteration:"AElAn fylm AllS AlZryf dryd lHAm wnylly fy synmA Almtrwbwl fy byrwt 16 kAnwn AlAwl 2015"

In English: "The 'Cute Thief' movie by Duriad Laham and Nelly, will be shown on Metropolis cinema in Beirut on 16 December 2015"

POS: اعلان/NN فيلم/NN اللص/NN الظريف/DTNNP دريد/NNP ل/IN حام/NN و/CC نيللي/NN ف/NN ي/PRP$ سينما/NN المتروبول/DTNN ف/CC ي/PRP$ بيروت/NNP 16/CD كانون/NN الاول/ADJ 2015/CD

اعلان فيلم اللص الظريف دريد لحام ونيللي في سينما المتروبول في بيروت 16 كانون الاول 2015

"The cute Thief " movie by Duriad laham and Nelly will be shown on Metropolis cinema in Beirut on 16 December 2015.

Event Trigger
Event product
Agent
Event Location
Event Time
Event Target

Fig. 1: Example for an Arabic tweet and its POS tags, the same tweet is tagged with the event arguments.

(a) a regular term frequency inverse document frequency (TF-IDF) based system and (b) the 'aboutness' system. The 'aboutness' system achieved F-measure value of 0.67 whereas the regular TF-IDF system achieved a 0.66 F-measure score.

Focusing on Arabic data, Alsaedi and Pete [14] train a Naïve Bayes classifier on Arabic tweets to extract events as part of a framework to apply a supervised approach to classify, cluster and summarize events. Worth noting that, this research is the only one available for extracting events from Arabic tweets.

In contrast to previous work on event extraction from Arabic text in general and from Arabic noisy text in particular, our approach focuses on extracting events with their related entities from Arabic tweets and link them to their corresponding entities in the event knowledge base. This enables our approach to provide appealing interactive interfaces of events such as a calendar or a time-line. Moreover, maintaining a knowledge base of events that can be used for event temporal resolution when more than one tweet are referring to the same event using different temporal expressions. Additionally, our approach is extracting events independently of the event type or event domain which makes it more applicable. Adopting an unsupervised technique based on syntactic rules fosters our approach to be more scalable.

III. Proposed Approach

For each tweet, proposed approach extracts named entities associated with their event phrases and specific events arguments. Event expressions may consist of the following arguments:

- **Event Agent:** represent the event initiator and the event participants.
- **Event Location:** refers to the city, country, or continent of the event location.
- **Event Target:** where the event is taking place within the event location (e.g. name of an organization, or facility).
- **Event Trigger:** the linguistic expression of the tweet that refers to the event expression.
- **Event Product:** in some cases the event is announcing a product.
- **Event Time:** is the tweet expression indicating the date/time of the event.

Figure 1 depicts an example of an Arabic tweet for a movie screening event with its annotated event arguments. The proposed knowledge-based approach extracts all the event arguments (discussed earlier) if they are mentioned in the text.

A. Data collection and Annotation

The Dataset was collected using Twitter Streaming API. The crawler was configured to search Arabic tweets using a set of temporal keywords, including ”today”, ”tomorrow”, names of weekdays, months, etc. A large number of tweets have been collected whereas only 3K tweets were left after filtering. As we are using an unsupervised approach of event tagging, we have evaluated our approach on a subset of 1000 tweets covering different domains and written by different users. Output of the approach annotation was manually evaluated by one of this paper authors. For each event, the evaluator checks the correctness of the extracted event's entities – i.e. trigger, agent, product, target, location, and time. In total the dataset consists of 122 events of the type interval and 878 events of the type instant.

B. Text Preprocessing

For text preprocessing, the AraNLP package was used. AraNLP is a Java-based package that contains services for text tokenization and normalization, POS tagging, and stemming [21]. During this phase tweets text were cleaned where non-Arabic words, hyperlinks, hash-tags, Arabic diacritics such as “ًٌٍَُِّْ”, punctuations and symbols such as “? ' ! @ $ # |”, were removed. Then text was normalized by removing “HAMZA/ء” from the “ALEF/ا” (i.e., the “آ أ إ” where all were replaced with the abstract version of the letter “ا”). Moreover, the ”TAA MARBUTAH/ة” was replaced with ”HAA/ه”, and the ”YAA/ي” was replaced with ”DOTLESS YAA/ى”.

As hash-tags may refer to an event argument (entity), only the hash symbol (#) was removed. Tweets were POS tagged using the Stanford POS tagger as part of AraNLP tool [21] (see Figure 1). Moreover, named entities in the tweet text were automatically annotated and disambiguated using the hybrid approach of machine learning and linked data [22].

C. The Events Ontology

As this research aims at extracting and representing events out of Arabic tweets with the ability to provide services for events visualization (e.g. Calendar, Time-line, etc.), an ontological knowledge base has been designed to represent extracted events. The knowledge base adopts a linked data approach where entities are linked through a set of knowledge bases (e.g. Wikipedia, DBpedia [23], [24], YAGO [25], and Freebase[1]). More precisely, our approach links tweets' entities with their corresponding entities in the Wikipedia and DBpedia knowledge bases. Moreover, for the sake of event extraction our knowledge base has been extended to link entities with their events through adopting the so called Event Ontology [26] and OWL-Time ontology [27]. The Event Ontology – was designed in 2004 as part of a research for modeling Music production process [28] – enables a flexible extension to model events where event participants are represented through the Agent concept based on Friend-of-a-Friend vocabulary

```
@prefix event: <http://purl.org/NET/c4dm/event.owl#>.
@prefix geo: <http://www.w3.org/2003/01/geo/wgs84_pos#>.
@prefix foaf: <http://xmlns.com/foaf/0.1/>.
@prefix tl: <http://purl.org/NET/c4dm/timeline.owl#>.
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>.
event:اعلان_فيلم
    a event:Event;
     event:agent[
        a foaf:Person;
        foaf:name "دريد لحام";
        foaf:agent <https://ar.wikipedia.org/wiki/دريد_لحام>;
        ];
    event:place <https://ar.wikipedia.org/wiki/بيروت>;
    event:time [
        a tl:Instant;
        tl:at "2015-12-16T00:00:00"^^xsd:dateTime;
     ];
    event:product "اللص الظريف";
    event:target "سينما المتروبول";
.
```

Fig. 2: RDF/TURTLE representation for Example 1 using the Event ontology.

(FOAF [29]), the event location is represented using Geospatial vocabulary, and the Event time is represented based on OWL-Time ontology where events are defined either as instant or interval. Nevertheless, some events announce a product which is also covered in the ontology.

In the proposed approach, the events ontology represents the main knowledge base for the events extracted from Arabic tweets. All extracted events based on our approach are populated to the events ontology. The represented events are then used to generate a Calendar or Time-line of events based on the user interests. Figure 2 provides the Resource Description Framework (RDF) represented using the TURTLE notation for the representation of Example 1 as populated to the events ontology.

D. Events Extraction and disambiguation

The process of extracting events out of tweets consists of three sub-processes: (i) Extracting Event mentions, (ii) Named entity recognition and disambiguation, and (iii) Temporal resolution.

1) Extracting Event mentions: In order to extract event mentions from Arabic tweets, a rule-based approach has been used to extract an event trigger, event time, and identify event type (i.e. instant or interval). The rule-based system has been designed based on the Arabic Annotation Guidelines for Events [30]. The guidelines are provided by the Linguistic Data Consortium (LDC) as part of their programs to foster Automatic Content Extraction (ACE) with tools, corpora, and guidelines. The guidelines have been mapped into syntactic rules that use POS tags of the tweet to extract event expression (i.e. event trigger and event time).

In order to extract the event trigger the following rules have been used:

- If the tweet has a Verb (VB or VBP) tag then

[1] http://www.freebase.com/

three possible syntactic cases can be applied to extract the event trigger, These rules are:

a **VB +NN:** If the next word is Noun(NN), then the event trigger will be the verb word followed by the noun word, in the above example the event trigger will be ("اعلان فيلم"/Movie announcement).

b **VB+VB:** If the next word is a verb (VB/VBN), then the event trigger will be the first verb with the second verb. For instance, " ساره حاولت قتل ماري/ sArh HAwlt qtl mAry /Sara Tried to Kill Marry" (حاولت/ HAwlt /Tried) is a verb and (قتل/ qtl/Kill) is also a verb so the event will be (حاولت قتل / HAwlt qtl/Tried to kill).

In case of none of these two rules has applied to the tweet, the event trigger will be only the extracted verb (VB). For example "فرنس24: زعيم متمردي جنوب السودان يعلن بانه سيعود الى جوبا في كانون الاول- ديسمبر / frns24: zEym mtmrdy jnwb AlswdAn yEln bAnh syEwd Ala jwbA fy kAnwn AlAwl-dysmbr /France24: The leader of south Sudan Rebels announced that he will return back to Juba in December. ", the tool will fail to extract any event trigger using the above rules, so the verb (يعلن / yEln/ announce) will be extracted as the event trigger.

- If the tweet has a Noun (NN or NNP) tag, at this case we have two possible rules:

a **NN+NN:** if the next word or next two words are also a Noun such as "عطله عيد الاضحى من الاربعاء الى السبت / ETlh Eyd Al-ADHA mn AlArbEa Ala Alsbt /Eid Adha Holydays from Wednesday to Saturday", then the event trigger will be "عطله عيد الاضحى/ ETlh Eyd AlADHA /Eid Adha Holydays" as the POS for "عطله/NN عيد/NN الاضحى/NNP".

b **NN/NNP Only:** At some cases the event trigger could be only a Noun. For example "العطله من الاربعاء الى السبت /AlETlh mn AlArbEA Ala Alsbt/The Holydays from Wednesday to Saturday/" here the Noun is (العطله / AlETlh /Holydays) so the event trigger will be (العطله/AlETlh /Holydays).

c **NN/NNP + VB/VBP:** At some cases the event trigger could be only a verb. For example "حفلتي سوف تقام يوم الثلاثاء/ Hflty swf tqAm ywm AlvlAvA /My party will be held on Tuesday", this sentence has a verb or a verb-phrase (تقام / will be held) which is proceeded by NN or NNP (حفلتي / My party/ Hflty). In such cases the VB/VBP (تقام / will be held/ tqAm) is used as the event trigger.

In order to extract the event time, the following rules have been used:

- If we have a Cardinal number (CD) tag for any part of the words of the text there are two possible syntactic rules to extract the event time from the text, These rules are:

a **CD + DTNN:** If the next word is a Determiner (DTNN), then the event time will be the CD+DTNN words. For example "موعد الحفل 5 ايار/ mwEd AlHfl 5 AyAr /the concert time is on 5 May ", the time trigger will be (5 ايار AyAr/ 5 May) as the POS tag for "5" is CD and for (ايار / AyAr /May) is DTNN.

b **CD + DTNN +CD:** If the next word is a (DTNN) and the next-next word is a (CD), then the Time trigger will be the three words together (CD + DTNN + CD). For example (سوف تقام المباراه في 5 ايار 2016 / swf tqAm AlmbArAh fy 5 AyAr 2016 / The match will be held on 5th of May 2016) the time trigger will be (5 ايار 2016 / 5 AyAr 2016/ 5 May 2015) as "5" is tagged as CD, (ايار/ AyAr /may) is tagged as DTNN, and "2016" is tagged as CD.

TABLE I: Syntactic rules for Event Trigger extraction.

Tweet POS Tag	Event Trigger
Verb (VB)/ Verb phrase (VBP)	VB+NN
	VB+VB
Noun (NN) / Noun phrase(NNP)	NN+NN
	NN/NNP Only
	NN/NNP + VB/VBP
Only Verb (VB)	VB
Cardinal number (CD)	CD + DTNN
	CD + DTNN +CD

Tables I summarize the syntactic rules that were used to extract the events triggers. For defining the event type (i.e. instant or interval), the system checks whether the tweet text has more than one event time and/or specific temporal expressions (keywords). Table II gives some examples for both types. For instance "تقام الحفله الموسيقيه من الساعه 5 الى الساعه 8 / tqAm AlHflh Almwsyqyh mn AlsAEh 5 Ala AlsAEh 8 /The concert will be held from 5 to 8 o'clock", two times represented in hours are provided in this tweet and are separated by the time keyword(من - إلى / from - to) which indicates an event with an interval type.

2) Named Entity Recognition and Disambiguation: For all the tweets that have been detected to hold an event, the system tags the missing events' arguments represented by (a) Event Agent, (b) Event Location and (c) Event product. The event agent can be represented by the persons or organizations participating / affected by the event, whereas the event location holds information about the place of the event. These arguments are represented as entity mentions in the tweet text. Therefore, in this step a named entity recognizer is used to tag these entities.

Extracting the entities mentioned in the event text is not enough, the approach requires linking the discovered entities with their corresponding in the knowledge base. Hence named entity disambiguation step is required. To this end, we employed the tool provided by [22] where a hybrid approach using machine learning and linked data is used to tag and disambiguate entities of the types: person, location, and organization. The disambiguation procedure in this tool is done based on information extracted form Arabic/English Wikipedia and DBpedia graph knowledge base. The tool was tested on a dataset that consist of

TABLE II: Some of the keywords used to indicate event type.

Event Type	Keywords Used
Instant	"تمام الساعه /at specific time/tmAm AlsAEh", "يوم محدد/specific day/ywm mHdd", etc.
Interval	"الفترة/period/"Alftra", "يستمر/continue/ystmr" ,"خلال/through/xlAl", etc.

over 10k entity mentions from different domains such as; technology, sport and politics. The results shows that the approach was able to correctly annotate 8,494 entity mentions out of 10,068 entity mentions, with an accuracy of 84% on the over whole dataset. Moreover the results based on the entity type were: 76% for the Person entities, 94% for the Location entities, and 78% for the Organization entities [cite Omar paper]. This hybrid approach has been also extended to disambiguate (link) extracted events to their corresponding events in the knowledge base as part of the temporal resolution step.

3) Temporal resolution: After extracting events and their entities, an entity linking step is needed. During this phase event arguments are linked to their corresponding entities in the knowledge base. This ensures better integration of extracted information with available ones, and eliminates duplicates from the knowledge base. Moreover, an event can be mentioned in tweets using different ways. For instance the same calendar date can be represented using different event time expressions, for example "next month" and "December, 2015" or "next Monday" and "December 16th" can all refer to the same calendar date based on the date of tweet writing. Entity linking is used to resolve the temporal expressions extracted out of the tweets. For each extracted event, the event arguments are linked to their corresponding in the knowledge base. A new event is populated to the knowledge base if and only if its arguments are not already represented there.

IV. Evaluation and Results

The results are obtained out of evaluating the proposed approach accuracy on three tasks namely: (T1) event trigger extraction, (T2) event time extraction, and (T3) event type identification. Evaluation results are measured using the approach accuracy where the number of the correctly predicted values for the three tasks are divided by the overall number of tweets (i.e. 1000). Out of the 1000 tweets of events, 122 events were of the type interval and 878 events were of the type instant.

TABLE III: Evaluation results for the three tasks using the accuracy measure.

Task	Accuracy
T1: Event Trigger Extraction	75.9%
T2: Event Time Extraction	87.5%
T3: Event Type Identification	97.7%

As presented in Table III, for T1: event trigger extraction, the approach managed to extract correctly 759 event triggers out of 1000 (Accuracy = 75.9%), whereas for T2: event time extraction, 875 event times were correctly extracted out of 1000 (Accuracy = 87.5%), and finally for T3: event type identification, 977 event types were correctly classified out of 1000 tweets (Accuracy = 97.7%).

TABLE IV: Accuracy for the three tasks based on the event type.

Task	Event Type	
	Instant	Interval
T1: Event Trigger Extraction	75.5%	78.6%
T2: Event Time Extraction	86.7%	92.6%
T3: Event Type Identification	97.9%	95.9%

In order to focus on the results in more detail, extraction results based on event type were evaluated. Table IV presents the approach accuracy results for the three tasks based on each event type. For the instant event type, T1: event trigger extraction accuracy is (663/ 878 = 75.5%), T2: Event time extraction accuracy is (762 / 878 = 86.7%), and T3: event type accuracy is (860/ 878= 97.9%). Whereas for the interval event type, T1: event trigger extraction accuracy is (96 / 122= 78.6%), T2: Event time extraction accuracy is (113/ 122= 92.6%), and T3: event type accuracy is (117 correct / 122= 95.9%).

V. Discussion

After analyzing the approach results on the three tasks, the following limitations can be summarized:

- Errors in the POS tagging: for some cases the tags assigned to the tweet tokens were incorrect. This leads into having a violation in some of the syntactic rules and yields to an incorrect extraction especially in the first two tasks, event trigger extraction and event time extraction.
- Conflict between rules: this case happens when two or more syntactic rules are fired. This problem mainly happens in the first two tasks, event trigger extraction and event time extraction. For example "تنطلق في تمام الساعة 5 مباراة الفجيرة الظفرة على ستاد الفجيرة الرياضي ضمن دوري الخليج العربي/ tnTlq fy tmAm AlsAE 5 mbArA Alfjyr AlZfr Ela stAd Alfjyr AlryADy Dmn dwry Alxlyj AlErby/It kicks off at 5 pm match Fujairah and the Fujairah Dhafra Sports Stadium within the Arabian Gulf League", in this case, the system extracts "ستاد الفجيرة / stAd Alfjyr / Fujairah Dhafra Sports Stadium" as the event trigger uses the NN+NN syntactic rule whereas the correct event trigger should follow the rule VB and extracts (تنطلق / tnTlq / kicks off) as the right event trigger.

The two problems mentioned earlier happen due to the limitations in the used POS tagger. The used POS tagger uses a phrase structure (PS) instead of dependency structure (DS) when annotating sentences. The difference between the two approaches is mainly in the POS tree where the words in the PS are the leaves and syntactic categories such as noun phrase (NP) and verb phrase (VP) represents the internal nodes, whereas in the DS the tree nodes are represented using the sentence words [31]. The problem is discussed in more details in [32]. Possible solution could be through using a DS-based POS tagger such as The Columbia Arabic Tree Bank (CATiB) [33], [34] or The Prague Arabic Dependency Treebank (PADT) [35], [36].

VI. Conclusion and Future Work

In this paper we present a knowledge-based approach for extracting events out of Arabic tweets. The approach uses an unsupervised rule-based approach for Event extraction and a Named entity disambiguation system to map each entity mention to their corresponding entities that are represented in the knowledge base. Results show that the approach has an accuracy of, 75.9% for T1: event trigger extraction, 87.5% for T2: event time extraction, and 97.7% for T3: event type identification.

Regarding enhancing the results of the rule-based approach we plan to use dependency structure based POS tagger - such as PADT and CATiB - instead of the current applied one. DS-based POS taggers builds on both syntactic and semantic features while tagging words, for instance they have semantic tags for time (TMP) and location (LOC). Moreover, DS-based POS taggers are capable to tag the head of the sentence which is most of the time the same event trigger to be extracted.

As for future plans we are currently annotating manually the whole 3K dataset of tweets where part of it will be used to train a supervised approach to extract event triggers and types using sequence labeling techniques such as Conditional Random Fields [35, 5]. Other classifiers can also be used to evaluate the features of POS and NER and results will be compared to the proposed rule-based approach.

References

[1] J. Allan, R. Papka, and V. Lavrenko, "On-line new event detection and tracking," in *Proceedings of the 21st annual international ACM SIGIR conference on Research and development in information retrieval.* ACM, 1998, pp. 37–45.

[2] J. Pustejovsky, P. Hanks, R. Sauri, A. See, R. Gaizauskas, A. Setzer, D. Radev, B. Sundheim, D. Day, L. Ferro *et al.*, "The timebank corpus," in *Corpus linguistics*, vol. 2003, 2003, p. 40.

[3] E. Gabrilovich, S. Dumais, and E. Horvitz, "Newsjunkie: providing personalized newsfeeds via analysis of information novelty," in *Proceedings of the 13th international conference on World Wide Web.* ACM, 2004, pp. 482–490.

[4] N. Chambers and D. Jurafsky, "Template-based information extraction without the templates," in *Proceedings of the 49th Annual Meeting of the Association for Computational Linguistics: Human Language Technologies-Volume 1.* Association for Computational Linguistics, 2011, pp. 976–986.

[5] C. X. Lin, B. Zhao, Q. Mei, and J. Han, "Pet: a statistical model for popular events tracking in social communities," in *Proceedings of the 16th ACM SIGKDD international conference on Knowledge discovery and data mining.* ACM, 2010, pp. 929–938.

[6] H. Becker, M. Naaman, and L. Gravano, "Beyond trending topics: Real-world event identification on twitter," 2011.

[7] E. Benson, A. Haghighi, and R. Barzilay, "Event discovery in social media feeds," in *Proceedings of the 49th Annual Meeting of the Association for Computational Linguistics: Human Language Technologies-Volume 1.* Association for Computational Linguistics, 2011, pp. 389–398.

[8] J. Lin, R. Snow, and W. Morgan, "Smoothing techniques for adaptive online language models: topic tracking in tweet streams," in *Proceedings of the 17th ACM SIGKDD international conference on Knowledge discovery and data mining.* ACM, 2011, pp. 422–429.

[9] A.-M. Popescu, M. Pennacchiotti, and D. Paranjpe, "Extracting events and event descriptions from twitter," in *Proceedings of the 20th international conference companion on World wide web.* ACM, 2011, pp. 105–106.

[10] A. Ritter, O. Etzioni, S. Clark *et al.*, "Open domain event extraction from twitter," in *Proceedings of the 18th ACM SIGKDD international conference on Knowledge discovery and data mining.* ACM, 2012, pp. 1104–1112.

[11] S. Abuleil, "Using nlp techniques for tagging events in arabic text," in *Tools with Artificial Intelligence, 2007. ICTAI 2007. 19th IEEE International Conference on*, vol. 2. IEEE, 2007, pp. 440–443.

[12] I. Saleh, L. Tounsi, and J. van Genabith, "Zaman and raqm: extracting temporal and numerical expressions in arabic," in *Information Retrieval Technology.* Springer, 2011, pp. 562–573.

[13] H. Aliane, W. Guendouzi, and A. Mokrani, "Annotating events, time and place expressions in arabic texts." in *RANLP*, 2013, pp. 25–31.

[14] N. Alsaedi and P. Burnap, "Arabic event detection in social media," in *Computational Linguistics and Intelligent Text Processing.* Springer, 2015, pp. 384–401.

[15] J. M. Pawlowski, M. Bick, R. Peinl, S. Thalmann, R. Maier, D.-W.-I. L. Hetmank, D.-W.-I. P. Kruse, M. Martensen, and H. Pirkkalainen, "Social knowledge environments," *Business & Information Systems Engineering*, vol. 6, no. 2, pp. 81–88, 2014.

[16] T. Berners-Lee, J. Hendler, O. Lassila *et al.*, "The semantic web," *Scientific american*, vol. 284, no. 5, pp. 28–37, 2001.

[17] T. Hasegawa, S. Sekine, and R. Grishman, "Discovering relations among named entities from large corpora," in *Proceedings of the 42nd Annual Meeting on Association for Computational Linguistics.* Association for Computational Linguistics, 2004, p. 415.

[18] W. Shen, J. Wang, P. Luo, M. Wang, and C. Yao, "Reactor: a framework for semantic relation extraction and tagging over enterprise data," in *Proceedings of the 20th international conference companion on World wide web.* ACM, 2011, pp. 121–122.

[19] D. Ahn, "The stages of event extraction," in *Proceedings of the Workshop on Annotating and Reasoning about Time and Events.* Association for Computational Linguistics, 2006, pp. 1–8.

[20] B. Sundheim, "Third message understanding evaluation and conference (muc-3): Phase 1 status report." in *HLT*, 1991.

[21] M. Althobaiti, U. Kruschwitz, and M. Poesio, "Aranlp: a java-based library for the processing of arabic text," 2014.

[22] M. Al-Smadi, B. Talafha, O. Qawasmeh, M. N. Alandoli, W. A. Hussien, and C. Guetl, "A hybrid approach for arabic named entity disambiguation," in *Proceedings of the 15th International Conference on Knowledge Technologies and Data-driven Business.* ACM, 2015, p. 27.

[23] J. Lehmann, R. Isele, M. Jakob, A. Jentzsch, D. Kontokostas, P. N. Mendes, S. Hellmann, M. Morsey, P. van Kleef, S. Auer *et al.*, "Dbpedia–a large-scale, multilingual knowledge base extracted from wikipedia," *Semantic Web*, vol. 6, no. 2, pp. 167–195, 2015.

[24] S. Auer, C. Bizer, G. Kobilarov, J. Lehmann, R. Cyganiak, and Z. Ives, *Dbpedia: A nucleus for a web of open data.* Springer, 2007.

[25] F. Mahdisoltani, J. Biega, and F. Suchanek, "Yago3: A knowledge base from multilingual wikipedias," in *7th Biennial Conference on Innovative Data Systems Research.* CIDR Conference, 2014.

[26] Y. Raimond and S. Abdallah, "The event ontology," Citeseer, Tech. Rep., 2007.

[27] J. R. Hobbs and F. Pan, "An ontology of time for the semantic web," *ACM Transactions on Asian Language Information Processing (TALIP)*, vol. 3, no. 1, pp. 66–85, 2004.

[28] Y. Raimond, S. A. Abdallah, M. B. Sandler, and F. Giasson, "The music ontology." in *ISMIR*. Citeseer, 2007, pp. 417–422.

[29] D. Brickley and L. Miller, "Foaf vocabulary specification 0.98," *Namespace document*, vol. 9, 2012.

[30] "Ace (automatic content extraction)arabic annotation guidelines for entities," 2008.

[31] F. Xia, O. Rambow, R. Bhatt, M. Palmer, and D. Misra Sharma, "Towards a multi-representational treebank," *LOT Occasional Series*, vol. 12, pp. 159–170, 2008.

[32] N. Y. Habash, "Introduction to arabic natural language processing," *Synthesis Lectures on Human Language Technologies*, vol. 3, no. 1, pp. 1–187, 2010.

[33] N. Habash and R. M. Roth, "Catib: The columbia arabic treebank," in *Proceedings of the ACL-IJCNLP 2009 conference short papers*. Association for Computational Linguistics, 2009, pp. 221–224.

[34] N. Habash, R. Faraj, and R. Roth, "Syntactic annotation in the columbia arabic treebank," in *Proceedings of MEDAR International Conference on Arabic Language Resources and Tools, Cairo, Egypt*, 2009.

[35] J. Hajic, B. Vidová-Hladká, and P. Pajas, "The prague dependency treebank: Annotation structure and support," in *Proceedings of the IRCS Workshop on Linguistic Databases*, 2001, pp. 105–114.

[36] J. Hajic, O. Smrz, P. Zemánek, J. Šnaidauf, and E. Beška, "Prague arabic dependency treebank: Development in data and tools," in *Proc. of the NEMLAR Intern. Conf. on Arabic Language Resources and Tools*, 2004, pp. 110–117.

Multivariable Decoupling Controller: Application to Multicellular Converter

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***Abstract*—A new control strategy is presented in this paper, based on previous works limited to the control of the capacitor voltages considered as the outputs of a three cell converter. An additional control input is proposed to this latter in order to obtain the desired current output. The experimentations performed on a multicellular converter are presented and the discussed results showing the efficiency of the contribution.**

***Keywords*—Hybride systems; Multicellular series converters; PWM; Closed loop control.**

I. INTRODUCTION

Industrial applications require electric power which may vary from a few kilowatts to megawatts of power [1], [2]. In order to achieve that purpose, there is a need to control the electrical power from the source before sending it to the load, hence the appearance of multicellular serie converters that were designed in 1990. The device is a multistage serie converter used to distribute the elevated voltage of the power source by dividing it over several cells and limit constraints voltages undergone by the semiconductor components. The latter adopt a switching behavior, the semiconductors can be either closed or opened, which changes the operation mode of the converter depending on the states of the switches. Hence, the electrical power output can be adapted according to the required load. Each cell of the converter is constituted by alternatively operating the two switches (if one is open the other is closed and alternatively). The switches are considered ideal, so their behavior can be modeled by a discrete state: the open state (value = 0) and the closed state (value = 1). Therefore, this system can be considered a hybrid system [3], as it contains continuous dynamic changes related to discrete variations. In the case of multicellular converter, the importance of the control strategy comes from the need for electrical power adapted to the load, but the high speed switching of the semi conductors causes the appearance of several unwanted harmonics in the output signal. This is where the different control techniques can stand trying to eliminate this undesirable effect [4]. Other requirements may also come into play, such as the energy level performance and power losses that have repercussions on the converter topology. In [5] a binary control was developed based on a Lyapunov function where the author proposed an algorithm that limits the number of the switches commutations to extend their durability. In the control strategy proposed in [6] the authors present a nonlinear decoupling input to a three cell converter, which is able to obtain good performances in controlling the capacitors voltages without regards to the current output, in fact only its average value was controlled. This paper proposes an additional control input to stabilize the instant value of the current output.

The following section start by introducing the system. Section three presents a nonlinear decoupling input control. Section forth describe the control schemes used on an experimental setup. Section fifth will conclude this paper.

II. MATHEMATICAL MODELING

Multicellular converter series are the association of several cells separated by capacitors. Each cell is formed by two complementary switches. The voltages across each cell must be kept well-defined to ensure the proper functioning of the entire system values. The following structures can be DC-DC converters (chopper operation), or as DC-AC (inverter operation) [5]. In general, the structure for p cells multicellular, Fig.1, have $(p-1)$ capacitors,$2p$ operating modes and $(p+1)$ voltage levels at the terminals of the capacitors.

In the case of a three cell converter there is eight operating modes. The following table gives the different configurations depending on the state of the switches (S_3, S_2, S_1) and the corresponding output voltages.

For modeling a multi-converter, we have two models:

1) The Exact Model or Snapshot: This model is only used to validate the controls. It is accurate because it takes exactly the switch status (On or Off) at any time. I_{ck} is the current through the capacitor and the signal $S_k = 0, 1$ are commands

TABLE I: MODE CONFIGURATION OF A THREE CELLS CONVERTER

	S3	S2	S1	V_{out}
Mode 0	0	0	0	0
Mode 1	0	0	1	$E/3$
Mode 2	0	1	0	$E/3$
Mode 3	0	1	1	$2E/3$
Mode 4	1	0	0	$E/3$
Mode 5	1	0	1	$2E/3$
Mode 6	1	1	0	$2E/3$
Mode 7	1	1	1	E

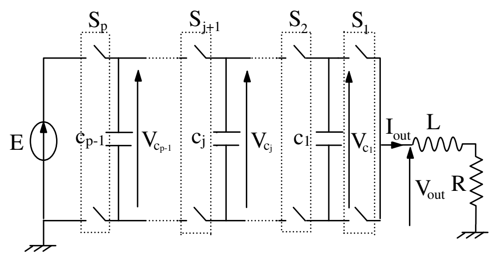

Fig. 1: Structure of a converter associated with a RL circuit as a load

of the switches (k = 1,2,3).

The current as a function of the control signals is of the form:

$$I_{ck} = (S_{k+1} - S_k)I_{out} \tag{1}$$

Also it can have the next form depending on the voltage across the capacitors:

$$I_{c_k} = C_k(\frac{dV_{c_k}}{dt}) \tag{2}$$

Combining the two equations (1) and (2) gives:

$$(\frac{dV_{c_k}}{dt}) = (\frac{S_{k+1} - S_k}{C_k})I_{out} \tag{3}$$

2) Equations of the tensions:

$$\frac{dV_{c_1}}{dt} = (\frac{S_2 - S_1}{C_1})I_{out} \tag{4}$$

$$\frac{dV_{c_2}}{dt} = (\frac{S_3 - S_2}{C_2})I_{out} \tag{5}$$

3) Equations of the currents:

$$I_{c_1} = C_1(\frac{dV_{c_1}}{dt}) \tag{6}$$

$$I_{c_2} = C_2(\frac{dV_{c_2}}{dt}) \tag{7}$$

According to the law of the meshes, the voltage Vs is the sum of the voltages across the switches:

$$V_{out} = \sum_{k=1}^{p}(V_{c_k} - V_{c_{k-1}})S_k \tag{8}$$

Where $V_{c_0} = 0V$ and $V_{c_p} = E$. The evolution of the current in the load is given by:

$$\frac{dI_{out}}{dt} = \frac{V_{out}}{L} - \frac{R}{L}I_c \tag{9}$$

By substituting (8) we obtain:

$$\frac{dI_{out}}{dt} = -\frac{R}{L}I_c - (\frac{S_2 - S_1}{L})V_{c_1} - (\frac{S_3 - S_2}{L})V_{c_2} + \frac{E}{L}S_3 \tag{10}$$

The state space model can be written as follows:

$$\begin{pmatrix} \frac{dV_{c_1}}{dt} \\ \frac{dV_{c_2}}{dt} \\ \frac{dI_{out}}{dt} \end{pmatrix} = \begin{pmatrix} 0 & 0 & \frac{S_2-S_1}{C_1} \\ 0 & 0 & \frac{S_3-S_2}{C_2} \\ \frac{S_1-S_2}{L} & \frac{S_2-S_3}{L} & -\frac{R}{L} \end{pmatrix} \begin{pmatrix} V_{c_1} \\ V_{c_2} \\ I_{out} \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ \frac{E}{L}S_3 \end{pmatrix} \tag{11}$$

An open loop control strategy was proposed in [7], were the control input is able to lead the system outputs to theirs corresponding references. The switches are controlled by pulses generated by the intersection between a triangular carrier signal and modulating, Fig. 2. The triangular signals are described by the following equations:

$$\begin{cases} f_1(u) = (\arcsin(\sin(2\pi f_p t - \varphi) + \frac{\pi}{2})/\pi \\ f_2(u) = (\arcsin(\sin(2\pi f_p t - \varphi - \delta) + \frac{\pi}{2})/\pi \\ . \\ . \\ f_p(u) = (\arcsin(\sin(2\pi f_p t - \varphi - (p-1)\delta) + \frac{\pi}{2})/\pi \end{cases} \tag{12}$$

The phase shift δ is equal to $2\pi/p$ which would reduce the harmonics of the output signal.

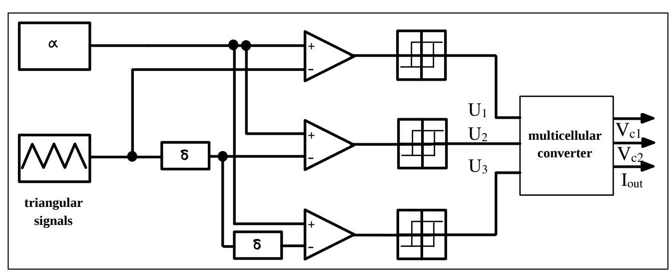

Fig. 2: PWM control strategy

The mentioned open loop control strategy generates several oscillations in the system outputs around their references. Also, the response of the system is very slow.

A. The average values Model

Let consider the system described in Fig. 2, the average model is based on the Fourrier series decomposition control signals. It allows a dynamic representation of the multicellular converter. It is assumed that the transitional regime is negligible. In this context, we can decompose in the Fourier series form each control function $S_k(t)$ as following [5]:

$$S_k(t) = a_0 + \sum_{p=1}^{+\infty}(a_p \cos(p\frac{2\pi}{T_D}t) + b_p \sin(p\frac{2\pi}{T_D}t)) \tag{13}$$

with $a_0 = \frac{1}{T_D}\int_0^{T_D} f(t)dt$ and $f(t) = \begin{cases} 1 \text{ for } t < t_\alpha \\ 0 \text{ for } t_\alpha < t < T_D \end{cases}$
thus $a_0 = \frac{1}{T_D}\int_0^{t_\alpha} dt = \frac{t_\alpha}{T_D}$
Having the duty cycle $\alpha = \frac{t_\alpha}{T_D}$ leads to $a_0 = \alpha$

In addition, the function $S_k(t)$ is pair, so $b_p = 0$ and

$$\begin{aligned} a_p &= \frac{2}{T_D}\int_0^{T_D} f(t)\cos(p\frac{2\pi}{T_D}t)dt \\ &= \frac{2}{T_D}\int_0^{\alpha_k T_D} \cos(p\frac{2\pi}{T_D}t)dt = u_{kp}(\alpha_k) \end{aligned}$$

Hence, the Fourier series decomposition of the control function has the following expression:

$$S_k(t) = \alpha_k + \sum_{p=1}^{+\infty}(u_{kp}(\alpha_k)\cos(p\frac{2\pi}{T_D}t)) \tag{14}$$

When passing to the average value equation (14) becomes $< S_k(t) >= \alpha_k$.

Each control variable is replaced by its average value over a period T_D, so the exact model described by equations (6), (7) and (8) becomes:

$$\begin{cases} < I_{c1} >= (\alpha_2 - \alpha_1)I_{out} \\ < I_{c2} >= (\alpha_3 - \alpha_2)I_{out} \\ < V_{out} >= \alpha_3 E + V_{c1}(\alpha_1 - \alpha_2) + V_{c2}(\alpha_2 - \alpha_3) \end{cases} \tag{15}$$

It uses the duty ratio as information for the switching cell.

Assuming floating voltages do not vary very much on the chopping period [7], we obtain: $V_{ck_{moy}}(t) \approx V_{ck}(t)$ which leads to the following equations:

$$\begin{cases} \frac{dV_{c_k}}{dt} = \frac{(\alpha_{k+1} - \alpha_k)}{c_k} I_{out} \\ \\ V_{out_{moy}} = \sum_{k=1}^{p}(V_{c_k} - V_{c_{k-1}})\alpha_k \end{cases} \tag{16}$$

So the average values model of a three cells converter will be as follows:

$$\begin{pmatrix} \frac{dV_{c_1}}{dt} \\ \frac{dV_{c_2}}{dt} \\ \frac{dI_{out}}{dt} \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & -\frac{R}{L} \end{pmatrix} \begin{pmatrix} V_{c_1} \\ V_{c_2} \\ I_{out} \end{pmatrix} + \begin{pmatrix} -\frac{I_{out}}{c_1} & \frac{I_{out}}{c_1} & 0 \\ 0 & -\frac{I_{out}}{c_2} & \frac{I_{out}}{c_2} \\ -\frac{V_{c_1}}{L} & -\frac{V_{c_2}}{L} & \frac{E}{L} \end{pmatrix} \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \end{pmatrix} \tag{17}$$

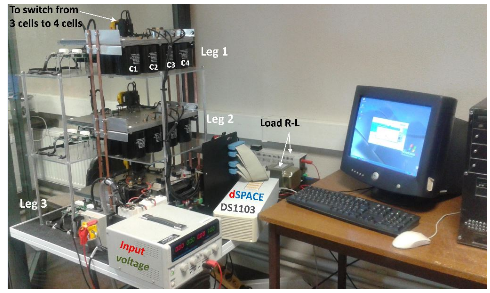

Fig. 3: The experimental setup

III. MATERIALS

The platform used to validate the next control technique is a system constituted of three legs initially connected to a three phase motor and replaced by a R-L load ($R = 20\Omega, L = 0.01mH$) for this application. We used a three-cell converter, see Fig. 3. The value of the capacitors between the cells are $C_1 = C_2 = C = 40\mu F$. The switches are bipolar transistors (IGBTs). Current and voltage measurements are obtained from voltage sensors and current transductors. The voltage source of the converter is $E = 60V$. A Matlab program script implementing the predictive algorithm was compiled and run by a DSPACE card. The card is used to control switch gates using its binary outputs, and receives measurements of the current and the two capacitor voltages through input card.

IV. EXPERIMENTAL RESULTS OF PWM CONTROL

The PWM (Pulse Width Modulation) control is a standard technique which can be used in case having a prime number of the cells in the converter [5]. It allows the control of the output current while keeping the voltages across the capacitors around the reference values.

We proceed with having: $\beta_3 = \alpha_3 - \alpha_1$ and $\beta_2 = \alpha_2 - \alpha_1$ we obtain:

$$\begin{pmatrix} C_1\frac{dV_{c_1}}{dt} \\ C_2\frac{dV_{c_2}}{dt} \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ -1 & 1 \end{pmatrix} \begin{pmatrix} \beta_2 \\ \beta_3 \end{pmatrix} I_{out} \tag{18}$$

And therefore:

$$\begin{pmatrix} \beta_2 \\ \beta_3 \end{pmatrix} = \frac{1}{I_{out}} \begin{pmatrix} 1 & 0 \\ -1 & 1 \end{pmatrix}^{-1} \begin{pmatrix} C_1\frac{dV_{c_1}}{dt} \\ C_2\frac{dV_{c_2}}{dt} \end{pmatrix} \tag{19}$$

If $c_1\frac{dV_{c_1}}{dt}$ and $c_2\frac{dV_{c_2}}{dt}$ are replaced by γ_2 and γ_3 we obtain :

$$\begin{cases} \beta_2 = \frac{\gamma_2}{I_{out}} \\ \\ \beta_3 = \frac{\gamma_3 + \gamma_2}{I_{out}} \end{cases} \tag{20}$$

Equation (20) is replaced in (15) leading to:

$$\begin{cases} < I_{c1} >= c_1 \frac{dV_{c_1}}{dt} = \beta_2 I_{out} = \gamma_2 \\ < I_{c2} >= c_2 \frac{dV_{c_2}}{dt} = (\beta_3 - \beta_2) I_{out} = \gamma_3 \\ < V_{out} >= (\alpha_1 + \frac{\gamma_2}{I_{out}} + \frac{\gamma_3}{I_{out}})E - \frac{\gamma_2}{I_{out}} V_{c1} - \frac{\gamma_3}{I_{out}} V_{c2} \end{cases} \quad (21)$$

From the system equations (21) we can see that $\frac{dV_{c_1}}{dt}$ and $\frac{dV_{c_2}}{dt}$ are decoupled but $< V_{out} >$ remain coupled. So, another decoupling control input is added to control the average value of the current output.
Suppose that $< V_{out} >= V_{ref} = RI_{ref}$, from equation (15) a decoupling control input can be as follows:

$$\alpha_1 = \frac{1}{V_{c1}} \left[V_{ref} - \alpha_3(E - V_{c2}) + \alpha_2(V_{c2} - V_{c1}) \right] \quad (22)$$

The principle is illustrated in the following figure 4 for a three-cell converter. Two controllers (PI) are assigned for regulating V_{c1} and V_{c2}.

In [5], the control strategy is able to drive the output voltages to their desired values but the current response presents several undulations around its set-point as shown in Fig. 5. The reason is related to the average model used in the control input (22) which lead obviously to control only the average value of the current output and not its instantaneous value, thus it allows the appearance of several oscillations around its reference.

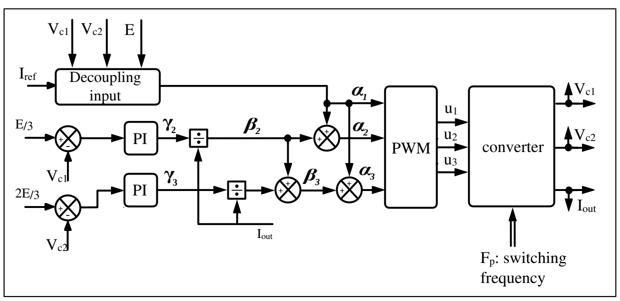

Fig. 4: Closed loop control strategy applied to a three-cell converter

To solve this problem, we associate another control term γ_1 that will be the output of a PI controller, the idea is inspired from [8] were the author combine a PID control action with a nonlinear control law. Thus the final expression controlling the current output will be the sum of a decoupling action and a PI control action.

$$\alpha_1 = \frac{1}{V_{c1}} \left[RI_{ref} - \alpha_3(E - V_{c2}) + \alpha_2(V_{c2} - V_{c1}) + \gamma_1 \right] \quad (23)$$

Which leads to a new structure of the overall control strategy (figure 6). An experimental results of the presented control scheme is conducted, where the frequency of the triangular signals $f_p = 1800Hz$ and the output references are as follows: $V_{c1_{ref}} = \frac{E}{3}$, $V_{c2_{ref}} = 2\frac{E}{3}$ and $I_{ref} = 1.5A$. The results are shown in Fig. 7, where it is shown that all the outputs follow theirs desired values.

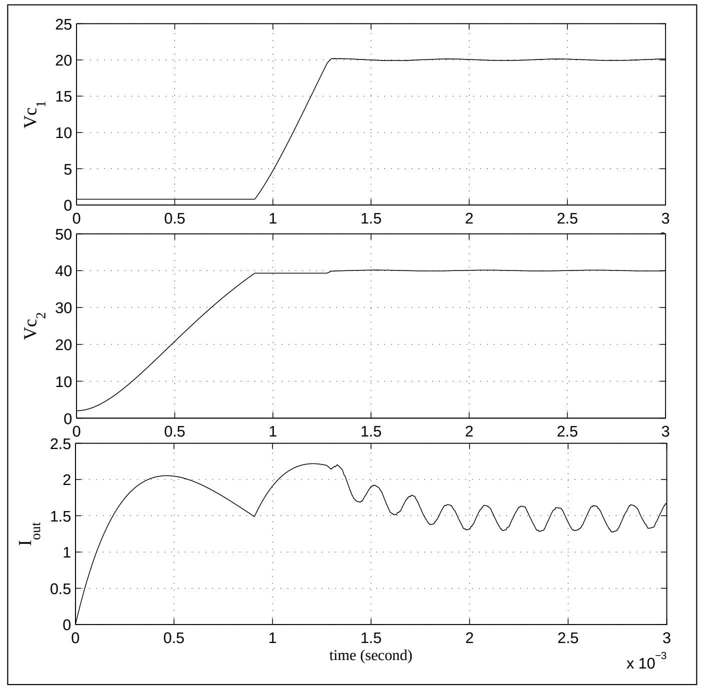

Fig. 5: Experimental results of the voltages across the capacitors (V_{c1} and V_{c2}) and the current output (I_{out}) evolution

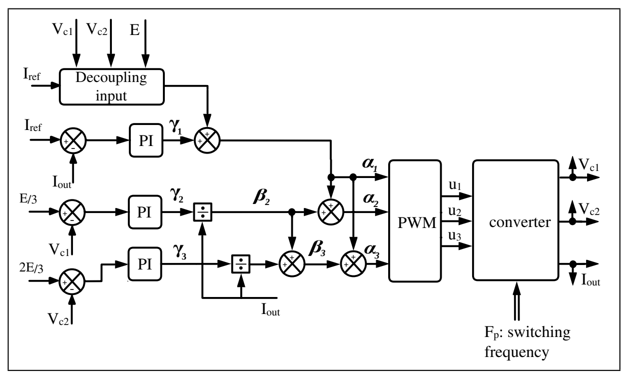

Fig. 6: The new proposed closed loop control strategy applied to a three-cell converter

V. Conclusion

Multicell converters are widely used in industrial applications because they offer the solution to control the electric energy between the source and the load. But, because of the discrete dynamic behavior of the semiconductors components, the system outputs present adverse effects (harmonics) that is possible to attenuate through an optimal control. The proposed control presented in this paper is based on an average model of the system, were after decoupling the system outputs from their inputs, we proceed to control the capacitor voltages. But, a problem arises in the current output were the decoupling control is not enough to attain good performances. In order to solve this problem, we added a PI control to the control input leading to acceptable performances.

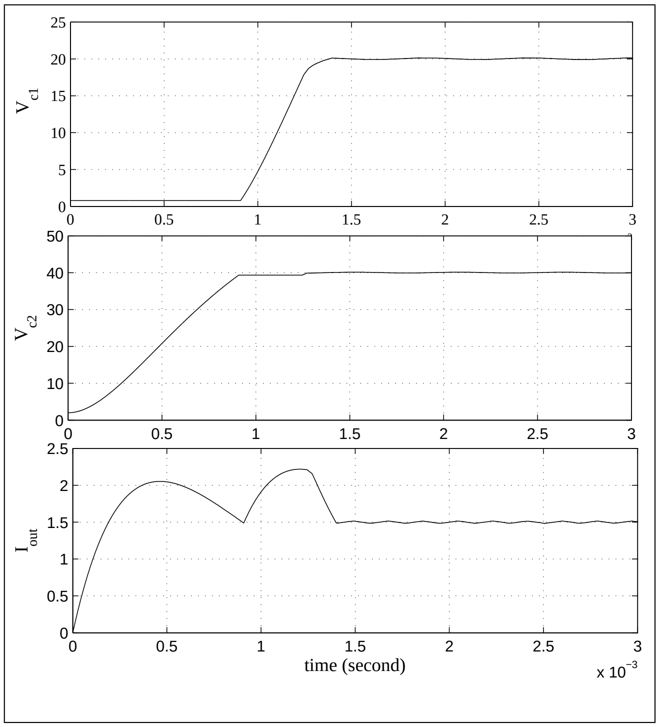

Fig. 7: Experimental results of the voltages across the capacitors (V_{c1} and V_{c2}) and the current output (I_{out}) evolution

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REFERENCES

[1] G. Gateau and M. Fades, *Multicellar converters : Active control and observation of flying capacitor voltages*, IEEE Trans. Industrial Electronics, Vol. 49, No. 5, 2002.

[2] T. A. Meynard, H. Foch, P. Thomas, J. Courault, R. Jakob, and M. Nahrstaedt, *Multicell converters: basic concepts and industry applications*, IEEE Transactions on Industrial Electronics, vol. 49, pp. 955 964, october 2002.

[3] K. Benmansour, A. Benalia , M. Djemai and J. deLion *Hybrid control of a multicellular converter, non linear analysis: Hybrid system*, 2007.

[4] P. Bartholomeus and Ph. Le Moigne. *A simple method for the valuation of the harmonics generated by multilevel converters*. ELECTRIMACS'96, Saint Nazaire, 17-18-19 Sept. 1996.

[5] O. Béthoux, " Commande et Détection de Défaillance d'un Convertisseur Multicellulaire Série ", Thèse de doctorat, Université de Cergy-Pontoise, pp. 16-18; 2005.

[6] J. Van Gorp, M. Defoort and M. Djemai, *Binary signals design to control a power converter*, 50th IEEE Conference on Decision and Control and European Control Conference (CDC-ECC) pp.12-15, Orlando, FL, USA, December , 2011

[7] M.Aimé, "Évaluation et optimisation de la bande passante des convertisseurs statiques : Application aux nouvelles structures multicellulaires", Thèse de doctorat, INPT, pp . 92-95, 2003.

[8] L. Michel, W. Michiels and X. Boucher, *Model-free control of nonlinear power converter*, The Canadian Conference on Electrical and Computer Engineering, 2013.

Performance of a Constrained Version of MOEA/D on CTP-series Test Instances

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***Abstract*—Constrained multiobjective optimization arises in many real-life applications, and is therefore gaining a constantly growing attention of the researchers. Constraint handling techniques differ in the way infeasible solutions are evolved in the evolutionary process along with their feasible counterparts. Our recently proposed threshold based penalty function gives a chance of evolution to infeasible solutions whose constraint violation is less than a specified threshold value. This paper embeds the threshold based penalty function in the update and replacement scheme of multi-objective evolutionary algorithm based on decomposition (MOEA/D) to find tradeoff solutions for constrained multiobjective optimization problems (CMOPs). The modified algorithm is tested on CTP-series test instances in terms of the hypervolume metric (HV-metric). The experimental results are compared with the two well-known algorithms, NSGA-II and IDEA. The sensitivity of algorithm to the adopted parameters is also checked. Empirical results demonstrate the effectiveness of the proposed penalty function in the MOEA/D framework for CMOPs.**

***Keywords*—Decomposition; MOEA/D; threshold based penalty function; constrained multiobjective optimization**

I. Introduction

This paper handles following type of constrained multiobjective optimization problem (CMOP) [1] [2]:

$$\begin{array}{ll} \text{Minimize} & F(x) = (f_1(x), f_2(x), \ldots, f_m(x))^T; \\ \text{Subject to} & g_j(x) \geq 0,\ j = 1, \ldots, p; \\ & l_k \leq x_k \leq u_k,\ k = 1, \ldots, n; \end{array} \qquad (1)$$

where $x = (x_1, \ldots, x_n)^T \in \mathcal{R}^n$ is an n dimensional vector of decision variables, F is the objective vector function that consists of m real-valued objective functions, and $g_i(x) \geq 0$ are inequality constraints (equality constraints, if any, can be transformed into corresponding inequality constraint as per common practice in literature). The objective and constraint functions, f_i's and g_j's, could be linear or non linear real-valued functions. l_k and u_k are the lower and upper bounds (called bound constraints) of x_k, $k = 1, \ldots, n$, respectively, which define the search region $\mathcal{S} = \{x = (x_1, \ldots, x_n)^T | \ l_k \leq x_k \leq u_k, k = 1, \ldots, n\}$.

A solution $x \in S$ is called a feasible solution, if it satisfies all the inequality constraints in (1). The set of all feasible solutions is called the feasible region. Mathematically, we can write: $\mathcal{F} = \{x \in \mathcal{S} \subset \mathcal{R}^n | g_j(x) \geq 0, j = 1, \cdots, p\}$. However, if a solution is not feasible, we call it infeasible. The set of all infeasible solutions is called the infeasible region. Moreover, the feasible attainable objective set (AOS) can be defined as $\{F(x)|x \in \mathcal{F}\}$.

In CMOPs, due to conflicting objectives, a single solution that could optimize all the objectives at the same time is often hard to be found. Therefore, in such problems, normally one has to look for a set of feasible optimal compromising/tradeoff solutions. Pareto-optimality [3], [4] defines the best tradeoffs among the conflicting objectives.

A solution x Pareto-dominates or simply dominates another solution y, mathematically denoted as $x \preceq y$, if $f_i(x) \leq f_i(y)$, $\forall i = 1, \ldots, m$ and $f_j(x) < f_j(y)$ for at least one $j \in \{1, \ldots, m\}$[1]. A solution $x^* \in \mathcal{F}$ is Pareto-optimal to (1) if there is no solution $x \in \mathcal{F}$ such that $F(x) \preceq F(x^*)$. $F(x^*)$ is then called a Pareto-optimal (objective) vector. The set of all Pareto-optimal solutions is called the *Pareto Set* (PS) in the decision space and *Pareto Front* (PF) in the objective space [3].

In most of the constrained optimization problems, the Pareto-optimal solutions lie on the constraints' boundaries Thus, to locate such solutions, a good practice could be to evolve some good infeasible solutions with small degree of constraint violation along with the feasible solutions during the evolutionary process (In [5]–[7] such practice has been adopted). The main goal of evolving infeasible solutions in the search process is to use the information they carry. Since EAs are stochastic search and optimization methods, so ignoring infeasible solutions might guide the EA being stuck in local optima, especially in CMOPs with disconnected search space [8], [9]. Additionally, finding a single feasible solution in some highly constrained optimization problems by itself could be a challenging problem [10], [11]. Therefore, one

[1]All the inequalities should be reversed if the purpose is to maximize the objectives in (1)

can distinguish different constraint handling techniques that are used in multiobjective optimization (MOO) by the way the infeasible solutions are mixed up and evolved with their feasible counterparts during the evolutionary process.

In [1], a threshold based penalty function is introduced. In order to penalize infeasible solutions, this penalty function uses a threshold value. The infeasible solutions with degree of constraint violation smaller than the threshold value are less penalized as compared to the ones with degree constraint violation greater than the threshold value. Consequently, a chance is given to some good infeasible solutions with less degree of constraint violation to evolve during the evolutionary process. In [12], the framework of MOEA/D-DE [13], an improved variant of MOEA/D [14] is modified for CMOPs; The modified framework is denoted by CMOEA/D-DE [12]. Two penalty parameterless constraint handling techniques are employed in this framework to solve CTP-series [4], [15] and CF-series [16] test instances. However, in this work, the threshold based penalty function is implanted in the replacement and update scheme of CMOEA/D-DE for handling constraints in CMOPs. As a result, a constrained version of MOEA/D-DE, denoted by CMOEA/D-DE-ATP is introduced. Empirical results have shown the capability of the proposed algorithm for handling hard CTP-series [4], [15] test instances.

The remainder of this paper is organized as follows. Section II presents a few basic concepts and the suggested threshold based penalty function. Section III introduces MOEA/D and adapts the algorithmic framework of MOEA/D-DE for CMOPs. Section IV presents and discusses experimental results on CTP-series [4], [15] test instances. This section also compares our experimental results with those of IDEA [7] and NSGA-II [17]. Section V provides some remarks on the sensitivity of the performance of CMOEA/D-DE-ATP to its parameters. Finally, Section VI concludes this paper.

II. Basic Concepts and the Proposed Threshold Based Penalty Function

A. Degree of Constraint Violation

The degree of constraint violation of a solution $x \in S$ can be defined as follows [1], [4]:

$$V(x) = |\sum_{j=1}^{p} \min(g_j(x), 0)|. \tag{2}$$

Clearly, $V(x) = 0$ implies that x is feasible; otherwise, it is infeasible.

B. Tchebycheff Aggregation Function

MOEA/D [14] decomposes an MOP into a number of scalar objective subproblems. In this paper, the Tchebycheff aggregation function is employed for this purpose, since it is less sensitive to the shape of PF, and it can be utilized to obtain the Pareto-optimal solutions in both convex and nonconvex PFs. It is defined as follows [18]:

$$\begin{array}{ll} \text{Minimize} & g^{te}(x|\lambda, z^*) = \max_{1\le i\le m}\{\lambda_i|f_i(x) - z_i^*|\}; \\ \text{Subject to} & x \in \mathcal{F} \subset \mathcal{R}^n; \end{array} \tag{3}$$

where $z^* = (z_1^*, \dots, z_m^*)^T$ is the reference point, i.e., $z_i^* = \min\{f_i(x)|x \in \mathcal{F}\}\ \forall i = 1, \dots, m$ and $\lambda = (\lambda_1, \dots, \lambda_m)^T$ is a weight vector such that $\lambda_i \geq 0\ \forall i = 1, \dots, m$ and $\sum_{i=1}^{m} \lambda_i = 1$.

C. The Threshold Based Penalty Function

Let us consider that MOEA/D [14] decomposes the MOP into N subproblems. In each iteration, MOEA/D retains N solutions $x^1, \dots, x^N$, where x^i is the current solution to subproblem i. Let us consider P to be the mating and update range in MOEA/D. Then define [1] [2]:

$$V_{min} = \min\{V(x^i), i \in P\}, \tag{4}$$

$$V_{max} = \max\{V(x^i), i \in P\}, \tag{5}$$

where $V(x^i)$ is the degree of constraint violation of solution x^i. The adopted threshold value, τ is then defined as follows [1] [2]:

$$\tau = V_{min} + s(V_{max} - V_{min}), \tag{6}$$

where the parameter s controls τ. In [1], we experimented with $s = 0.3$.

The threshold based penalty function not only encourages the algorithm to search the feasible region, but also the infeasible region close the feasible region for optimal solutions. It is defined as follows [2]: For $i = 1, \dots, m$

$$f_p^i(x) = \begin{cases} f_i(x) + s_1 V^2(x), & \text{if } V(x) < \tau; \\ f_i(x) + s_1\tau^2 + & \\ s_2(V(x) - \tau), & \text{otherwise,} \end{cases} \tag{7}$$

where s_1 and s_2 are two scaling parameters with $s_1 << s_2$. As can be observed from the penalty function, the penalty sharply increases when $V(x)$ is greater than the threshold. This is realized by scaling the degree of constraint violation, $V(x)$ of an infeasible solution by a relatively high value of parameter s_2 than parameter s_1.

III. Multiobjective Evolutionary Algorithm Based on Decomposition

Zhang and Li [14] introduced a simple yet efficient MOEA, named as multi-objective evolutionary algorithm based on decomposition (MOEA/D). In order to approximate the PF, MOEA/D employs an aggregation function to explicitly decompose an MOP into a number of scalar objective optimization subproblems (this work uses the Tchebycheff function to serve the purpose of decomposition). Then, an EA is employed to optimize these subproblems concurrently and collaboratively by evolving population of solutions. The Euclidean distances between the aggregation coefficient vectors of the subproblems are utilized to determine the neighborhood relations among them, which are then used to optimize a subproblem.

An improved version of MOEA/D, MOEA/D-DE is introduced in [13]. It distinguishes from its predecessor (MOEA/D) in the following aspects [13]:

- For maintaining population diversity, MOEA/D-DE takes two measures:
    1) It picks out three parent solutions from the whole population with a low probability $1-\delta$,

where $\delta = 0.9$ is the probability of selecting the parents from the neighborhood of a solution. Because of the dissimilarity among these parent solutions, a very wide range of child solutions could be brought about and, as a result, the exploration ability of the search could be ameliorated.

2) It limits the maximal number of solutions replaced by a better child solution by a parameter $n_r << T$, where T is the neighborhood size of the child solution. Thus, there is a little chance that a better child solution has many copies in the population. While, in MOEA/D, the maximal number of solutions replaced by a better child solution could be as large as T.

- Since DE [19] operators often surpass other genetic operators in single objective optimization, MOEA/D-DE benefits from DE operator for generating offspring.

The penalty function defined by Eq. 7 is employed in the update scheme of CMOEA/D-DE [12] to solve CTP-series [4], [15] test instances. This produced a new algorithm, denoted by CMOEA/D-DE-ATP. The pseudo-code of the update scheme of CMOEA/D-DE-ATP is given in Algorithm 1.

Algorithm 1 Pseudo-code of the Update Scheme of CMOEA/D-DE-ATP. n_r is the Number of Solutions Updated by a Better Child Solution.

1: Each new offspring y replaces n_r parent solutions from the set P of its neighboring solutions as follows:
2: Set $c = 0$ and then do the following:
3: **if** $c = n_r$ or $P = \emptyset$ **then**
4:     return;
5: **else**
6:     Choose randomly an index j from P;
7:     Calculate the Tchebycheff aggregation function values of y and x^j with the new objective values of Eq. 7;
8:     **if** $g^{te}(y|\lambda^j, z) \leq g^{te}(x^j|\lambda^j, z)$ (or $g_p^{te}(y|\lambda^j, z) \leq g_p^{te}(x^j|\lambda^j, z)$) **then**
9:         $x^j = y$, $F(x^j) = F(y)$, $V(x^j) = V(y)$, and $c = c + 1$;
10:     **end if**
11:     Remove j from P and go to step 3;
12: **end if**

IV. Experimental Results

In all experiments, the same parameters' settings as given in [12] are used. The weight vectors used in Eq. 3 are selected as per the proposed criteria in [16]. If not stated otherwise, Eq. 6 is used with $s = 0.3$ and Eq. 7 with $s_1 = 0.01$ and $s_2 = 20$ in all our experiments.

Hypervolume metric (HV-metric) computes the volume in the function space covered by the elements of a set P for problems with minimizing objectives [20], [21]. The HV-metric statistics are used to compare the experimental results obtained from CMOEA/D-DE-ATP on CTP-series test instances. To calculate the HV-metric values, the reference point (2, 20) is used for test instances CTP6 and CTP8, while it is (2,2) for the remaining test instances, CTP1-CTP5, CTP7.

Table I presents the HV-metric statistics based on 30 independent runs of CMOEA/D-DE-ATP when using Eq. 6 with $s = 0.3, 0.5, 0.7$ for the CTP-series test instances (the three different adopted values are intended to look at the behavior of the algorithm by evolving various percentages of infeasible solutions during the evolutionary process). These statistics are based on feasible solutions found in the final populations of each algorithmic run and include the best (i.e., highest), mean, and standard deviation values of the HV-metric.

For CTP1, the better best value is found by CMOEA/D-DE-ATP with all used parameter s values. However, for better mean and standard deviation values, it needs to be run with $s = 0.3$. For CTP2, the better best and mean values are found by CMOEA/D-DE-ATP with $s = 0.3$, while the better standard deviation value is found with $s = 0.5$. For CTP3, the better best value is found by CMOEA/D-DE-ATP with $s = 0.5$. However, for better mean and standard deviation values, it needs to be run with $s = 0.3$. For CTP4, CTP5, and CTP6, the better best, mean and standard deviation values are found with $s = 0.5$, $s = 0.3$, and $s = 0.7$, respectively. For CTP7 and CTP8, the better best value is found with $s = 0.7$, while the better mean and standard deviation values are found with $s = 0.3, 0.5$. Overall, better performance of the algorithm can be achieved, in terms of mean and standard deviation values, with $s = 0.3$.

Figure 1 plots, in the objective space, the nondominated solutions with the best (i.e., highest) HV-metric value found by CMOEA/D-DE-ATP in 30 independent runs for CTP-series test instances. In order to look at the variation of the nondominated solutions found by CMOEA/D-DE-ATP, all the 30 final nondominated fronts attained are also plotted in the same figure. This figure clearly shows that CMOEA/D-DE-ATP found good approximations of the PFs for all test instances except CTP4, where it can be noted that in some of the runs the obtained Pareto optimal solutions did not completely converge to the PF.

A. Comparison with NSGA-II and IDEA

This section compares the experimental results of CMOEA/D-DE-ATP with those of IDEA [7] and NSGA-II [17] on CTP-series test instances. Table II presents the HV-metric statistics, obtained from 30 independent runs of CMOEA/D-DE-ATP when using Eq. 6 with $s = 0.3$ and Eq. 7 with $s_1 = 0.01$ and $s_2 = 20$, IDEA with $\alpha = 0.2$ (α determines the percentage of infeasible solutions to be retained during evolution and NSGA-II with the constraint domination principle [17] for seven CTP-series test instances, CTP2-CTP8. The statistics of IDEA and NSGA-II are picked from [7], and are rounded to four decimal places. From this table, it can be seen that CMOEA/D-DE-ATP has found best HV-metric values for four test instances, CTP3, CTP5, CTP6 and CTP8 and the second best results for CTP4 and CTP7. NSGA-II and IDEA have found the best HV-metric value for CTP1 and CTP4, respectively, while for CTP7 both algorithms have obtained the same best HV-metric value. The table also shows that even with a small threshold value, CMOEA/D-DE-ATP has found better mean and standard deviation values

TABLE I: The HV-Metric statistics of CMOEA/D-DE-ATP with three different values of parameter s. The results in **boldface** and in *italic* show the better and the second better results. If not, they are same.

	best (highest)			mean			st. dev.		
Test Instance	$s = 0.3$	$s = 0.5$	$s = 0.7$	$s = 0.3$	$s = 0.5$	$s = 0.7$	$s = 0.3$	$s = 0.5$	$s = 0.7$
CTP1	2.7647	2.7647	2.7647	**2.7642**	*2.7638*	2.7615	**0.0006**	*0.0007*	0.0042
CTP2	**3.0591**	3.0564	*3.0580*	**3.0511**	*3.0492*	3.0477	*0.0174*	**0.0169**	0.0177
CTP3	3.0256	**3.0265**	*3.0257*	**3.0137**	*3.0012*	2.9816	**0.0242**	*0.0394*	0.0481
CTP4	2.8688	**2.9327**	*2.8778*	2.4736	**2.5531**	*2.5129*	*0.2058*	**0.2001**	0.2297
CTP5	**3.0313**	*3.0292*	3.0283	**3.0032**	3.0011	*3.0014*	**0.0201**	*0.0226*	**0.0201**
CTP6	36.8196	*36.8200*	**36.8202**	**36.8184**	*36.8181*	**36.8184**	*0.0017*	0.0027	**0.0012**
CTP7	*3.6125*	*3.6125*	**3.6128**	**3.6124**	**3.6124**	*3.6099*	**0.0001**	**0.0001**	*0.0138*
CTP8	36.1821	*36.1822*	**36.1825**	**36.1652**	36.1449	*36.1464*	**0.0342**	*0.0532*	0.0578

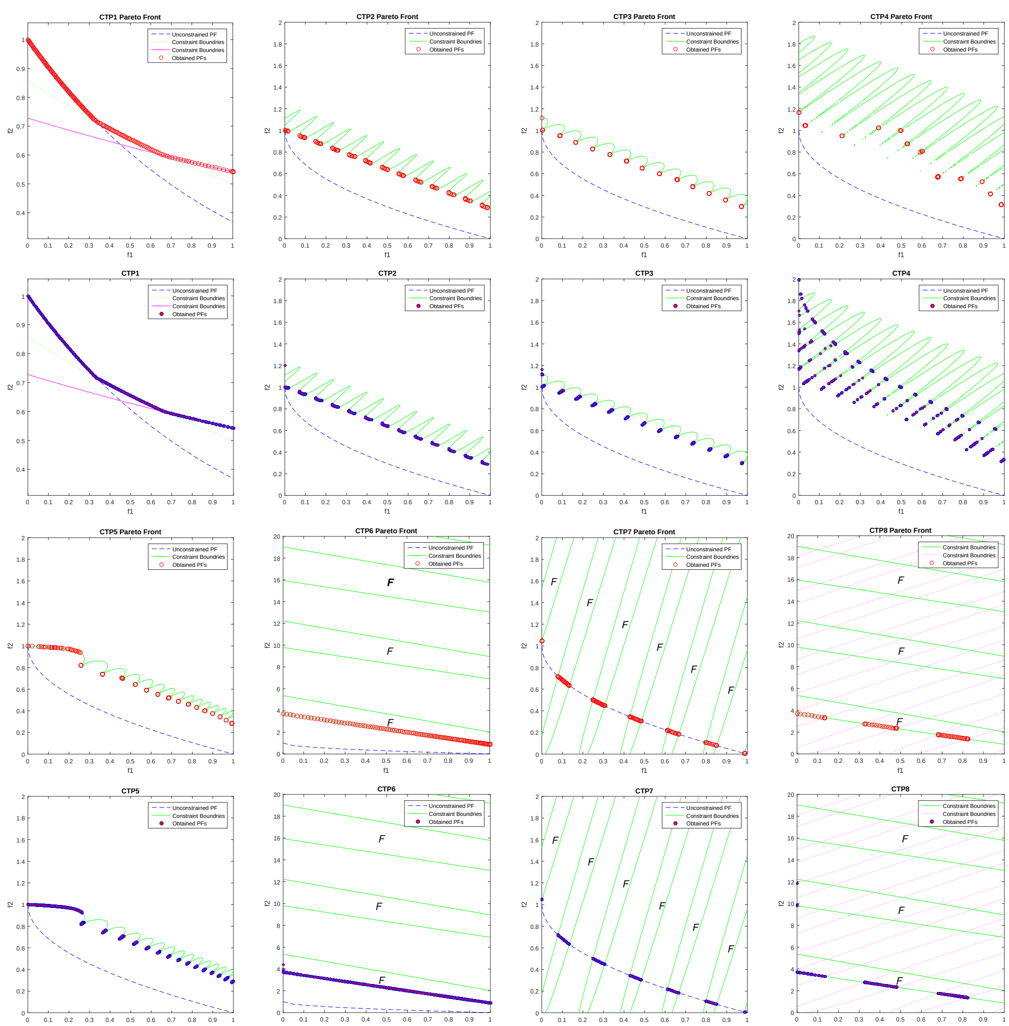


Fig. 1: Plots of the nondominated front with the best HV-metric value and all the 30 final nondominated fronts found by CMOEA/D-DE-ATP for CTP1 to CTP8.

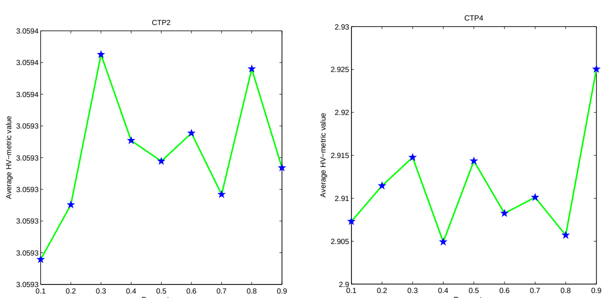
TABLE II: Comparison of CMOEA/D-DE-ATP (indicated by ATP) with IDEA and NSGA-II in terms of the HV-Metric statistics. The results in **boldface** and in *italic* indicate the better and the second better results.

	best (Highest)			mean			st. dev.		
Test Instance	ATP	IDEA	NSGA-II	ATP	IDEA	NSGA-II	ATP	IDEA	NSGA-II
CTP2	3.0591	*3.0592*	**3.0593**	**3.0511**	3.0114	2.8707	**0.0174**	*0.1771*	0.2701
CTP3	**3.0256**	*3.0160*	3.0104	**3.0137**	*2.9608*	2.8281	**0.0242**	*0.1638*	0.2547
CTP4	*2.8688*	**2.9190**	2.8485	*2.4736*	**2.7447**	2.4381	*0.2058*	**0.1393**	0.3527
CTP5	**3.0313**	*3.0247*	3.0209	**3.0032**	*2.9529*	2.7235	**0.0201**	*0.1621*	0.2926
CTP6	**36.8196**	36.8191	*36.8227*	**36.8184**	*36.7878*	36.1829	**0.0017**	*0.0758*	2.1873
CTP7	*3.6125*	**3.6177**	**3.6177**	**3.6124**	*3.4359*	3.2402	**0.0001**	0.5945	*0.5941*
CTP8	**36.1821**	*36.1804*	36.1708	**36.1652**	*35.9706*	32.0859	**0.0342**	*0.4345*	5.1763

than IDEA and NSGA-II for all test instances except CTP4, where IDEA supersede the two competitors. In particular, the standard deviation values obtained with CMOEA/D-DE-ATP are considerably better than the two algorithms. The small values of the standard deviation for CMOEA/D-DE-ATP suggests the consistent performance of it.

V. Sensitivity of CMOEA/D-DE-ATP to Its Parameters

This section analyzes the sensitivity of the the performance of CMOEA/D-DE-ATP to the proposed penalty function parameters – s, s_1 and s_2 and the algorithmic parameters– T, n_r, δ, N, CR, and F. In this regard, a comparatively simple test instance CTP2 and a hard test instance CTP4 are used. In CTP2, the PF consists of disconnected continuous Pareto-optimal regions, while in CTP4, an algorithm has to travel through long narrow feasible tunnels to find the lone Pareto-optimal solutions at the end of each tunnel.



(a) (b)

Fig. 2: The average HV-metric values vs. parameter s in CTP2 and CTP4.

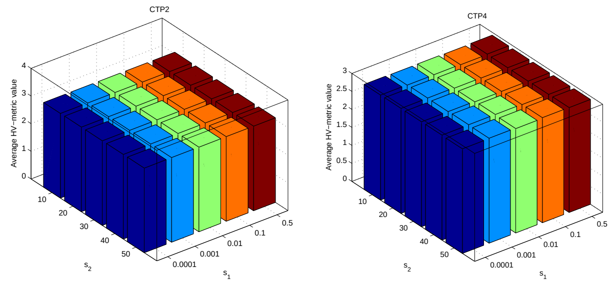
A. Sensitivity of CMOEA/D-DE-ATP to s

To study the sensitivity of the performance of CMOEA/D-DE-ATP to parameter s that controls the threshold, τ range where infeasible solutions are less penalized, 9 different values of parameter s (i.e., $s = 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9$) are used in CMOEA/D-DE-ATP for test instances CTP2 and CTP4. Figure 2 shows the average HV-metric values versus the values of parameter s. The figure clearly indicates the sensitivity of the performance of the algorithm to parameter s on different test instances. As can be seen from Figure 2 (a) that for test instance CTP2 the best (i.e., highest) average value of the HV-metric is found by CMOEA/D-DE-ATP with $s = 0.3$ (one can also see the value obtained with $s = 0.8$ is very close to the one obtained with $s = 0.3$), while for test instance CTP4, it is found with $s = 0.9$ (see Figure 2 (b)). This indicates that for test instances like CTP2 a small value of parameter s could be used to get a small value of τ and, as a result, a small infeasible region close to feasibility boundary is explored. This small value of τ allows a small number of infeasible solutions to survive, which results in achieving a higher HV-metric value. However, for hard test instances like CTP4, a higher value of parameter s could be used to get a larger value of τ and, thereby, a large infeasible region is explored along with the feasible ones in search of the lone Pareto-optimal solutions situated at the end of each disconnected narrow feasible regions. This allows a large number of infeasible solutions to be less penalized. As a result, these infeasible solutions will evolve along with feasible solutions found and thus result in obtaining a higher HV-metric value.

B. Sensitivity of CMOEA/D-DE-ATP to s_1 and s_2

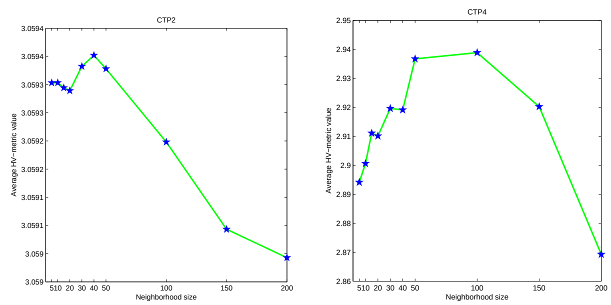
To study the sensitivity of the performance of CMOEA/D-DE-ATP to parameters s_1 and s_2, 25 different combinations of five values of s_1 (i.e., $s_1 = 0.0001, 0.001, 0.01, 0.1, 0.5$) and five values of s_2 (i.e., $s_2 = 10, 20, 30, 40, 50$) are tested in CMOEA/D-DE-ATP on test instances CTP2 and CTP4. Each combination of the two parameters is tried 30 times.

Figure 3 shows the average HV-metric values obtained by the algorithm with 25 different combinations of s_1 and s_2. It is obvious that CMOEA/D-DE-ATP is less sensitive to the settings of these two parameters under the considered ranges for test instances like CTP2 and CTP4.



(a) (b)

Fig. 3: The average HV-metric values obtained by CMOEA/D-DE-ATP with 25 different combinations of s_1 and s_2 on CTP2 and CTP4.



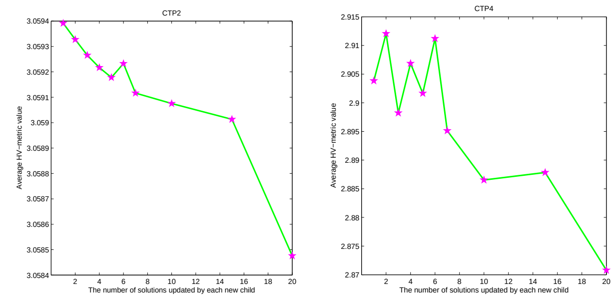
(a) (b)

Fig. 4: The average HV-metric values vs. the neighborhood size (T) in CTP2 and CTP4.

C. Sensitivity of CMOEA/D-DE-ATP to T

To study the sensitivity of the performance of CMOEA/D-DE-ATP to T, 10 different values of neighborhood size (i.e., $T = 5, 10, 20, 30, 40, 50, 100, 150, 200$) are used in CMOEA/D-DE-ATP for test instances CTP2 and CTP4.

Figure 4 shows the average HV-metric values versus the neighborhood size T. It is clear from this figure that the performance of CMOEA/D-DE-ATP is sensitive to the setting of neighborhood size T. For test instance CTP2, the best (i.e., highest) HV-metric value is found by CMOEA/D-DE-ATP with $T = 40$. One can see from Figure 4 (a) that CMOEA/D-DE-ATP with $T = 30$ and $T = 50$ can find the average HV-metric values very close to the one obtained with $T = 40$. This indicates that CMOEA/D-DE-ATP can still find the good approximation of the PF of CTP2 when the neighborhood size varies in an appropriate range. Figure 4 (a) also shows that CMOEA/D-DE-ATP with $T < 30$ or $T > 100$ (although, the HV-metric values with $T < 30$ are much better than those with $T > 100$) will be unable to find good approximation of the PF of CTP2 as with $T = 40$, because the average HV-metric values found are smaller than the one obtained with $T = 40$. This can be explained by the exploration and exploitation of the search space in CMOEA/D-DE-ATP. This explains that, on one hand, CMOEA/D-DE-ATP lacks the ability of exploring the search space with small T, while on the other hand, it is unable to exploit the PS well with large T. In the latter case, the mating parents could be apart from each other (i.e., very dissimilar) in the decision space. However, as can be seen from Figure 4 (b), T can be chosen from the range $50 < T < 100$ for better performance of the algorithm on test instance CTP4.



(a) (b)

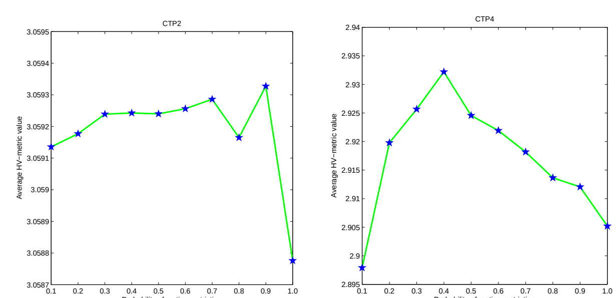
Fig. 5: The average HV-metric values vs. the maximal number of solutions updated by each new offspring (n_r) in CTP2 and CTP4.

D. Sensitivity of CMOEA/D-DE-ATP to n_r

To study the sensitivity of the performance of CMOEA/D-DE-ATP to n_r, 10 values of n_r (i.e., $n_r = 1, 2, 3, 4, 5, 6, 7, 10, 15, 20$) are tested in the algorithm for test instances CTP2 and CTP4.

Figure 5 presents the average HV-metric values versus the ten different values of n_r. As clearly shown in Figure 5 (a), CMOEA/D-DE-ATP with small $n_r = 1, 2, 3$ values can find the good approximation of the PF of CTP2. However, when n_r is large (i.e., ≥ 4), CMOEA/D-DE-ATP performs clearly worse in maximizing the HV-metric values.

For test instance CTP4, higher HV-metric value is achieved when $n_r = 2$ (see Figure 5 (b)), and when $n_r > 2$ except $n_r = 6$ (as the value of HV-metric obtained with $n_r = 6$ is very close the one obtained with $n_r = 2$), the values of the HV-metric get worsen.



(a) (b)

Fig. 6: The average HV-metric values vs. the probability of selecting mating parents from the neighborhood (δ) in CTP2 and CTP4.

E. Sensitivity of CMOEA/D-DE-ATP to δ

In order to study the sensitivity of the performance of CMOEA/D-DE-ATP to the probability of selecting mating parents from the neighborhood, δ, 10 values of δ (i.e., $\delta = 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0$) are tried in CMOEA/D-DE-ATP for test instances CTP2 and CTP4.

Figure 6 shows the average HV-metric values versus the values of δ. It is clear from Figure 6 (a) that CMOEA/D-DE-ATP with $\delta = 0.9$ has the best performance in terms of the HV-metric for test instance CTP2. This indicates that selecting 90% solutions from the neighborhood of a solution and 10% of the solutions from the whole population for recombination does improve the performance of CMOEA/D-DE-ATP on CTP2. In the latter case, the solutions that are apart from each other in the search space will get a chance to mate with a low probability. Although this procedure boosts the capability of CMOEA/D-DE-ATP to explore the search space, but still more computational efforts are utilized on the recombination between neighboring solutions in order to exploit the PS efficiently.

However, for better performance on test instance like CTP4, 40% of the solutions are needed to be selected from the neighborhood and 60% from the whole population for recombination (see Figure 6 (b)).

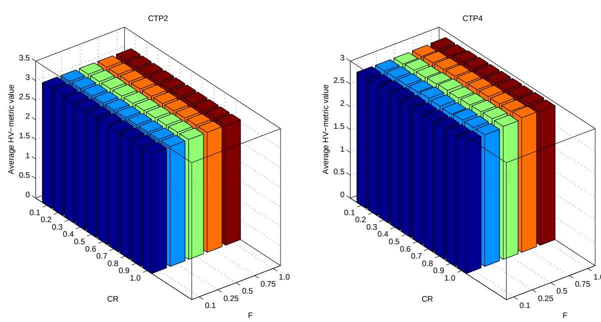
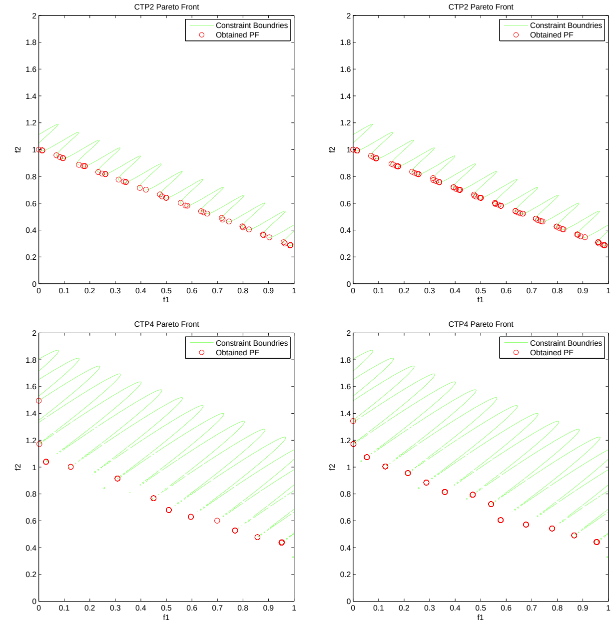


Fig. 7: The average HV-metric values obtained by CMOEA/D-DE-ATP with 50 different combinations of CR and F values on CTP2 and CTP4.

F. Sensitivity of CMOEA/D-DE-ATP to CR and F

The genetic operator DE employs two control parameters CR and F for generating offspring. To study the effects of these two parameters on the behaviour of CMOEA/D-DE-ATP, 50 combinations of five values of F ($F = 0.1, 0.25, 0.5, 0.75, 1.0$) and ten values of CR ($CR = 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0$) are tested on test instances CTP2 and CTP4. Each combination of CR and F is tested 30 times.

Figure 7 shows the average HV-metric values with 50 different combinations of CR and F values. It is evident from this figure that CMOEA/D-DE-ATP is less sensitive to the settings of CR and F under the considered ranges and test instances.



(a) (b)

Fig. 8: Plots of the final solutions obtained from CMOEA/D-DE-ATP with population sizes of 50 (column a) and 100 (column b) evolved over 200 generations for CTP2 and CTP4.

G. CMOEA/D-DE-ATP with Small Population

Decision makers (DMs) often show interest in a small evenly distributed population at a low computational cost. In the following, it is shown that CMOEA/D-DE-ATP adopting small population could attain this objective. CMOEA/D-DE-ATP is run with population sizes of $N = 50$ and $N = 100$ and 200 generations on test instances CTP2 and CTP4. Accordingly, the algorithm stops after $10,000$ and $20,000$ function evaluations.

Figure 8 plots the final solutions obtained in a single run of CMOEA/D-DE-ATP with $N = 50$ (column a) and $N = 100$ (column b) for test instances CTP2 and CTP4. It is very evident from this figure that CMOEA/D-DE-ATP found 50 and 100 evenly distributed solutions for test instances CTP2. However, for test instance CTP4, the 100 final solutions are evenly distributed along the PF, but the 50 final solutions, although evenly distributed, misses some Pareto-optimal solutions.

As it can be seen that test instances CTP2 and CTP4 have disconnected continuous/discrete Pareto-optimal regions/solutions. Thus, any Pareto dominance based algorithm that prefers feasible solutions over infeasible solutions in their selection/replacement schemes, like NSGA-II with the constraint-domination principle, is likely to face difficulty in capturing the whole PF until a large population size is used to maintain population diversity [7]. On the other hand, decomposition based algorithm like CMOEA/D-DE-ATP, which tries to keep some good infeasible solutions in its course of evolution can capture the whole PF.

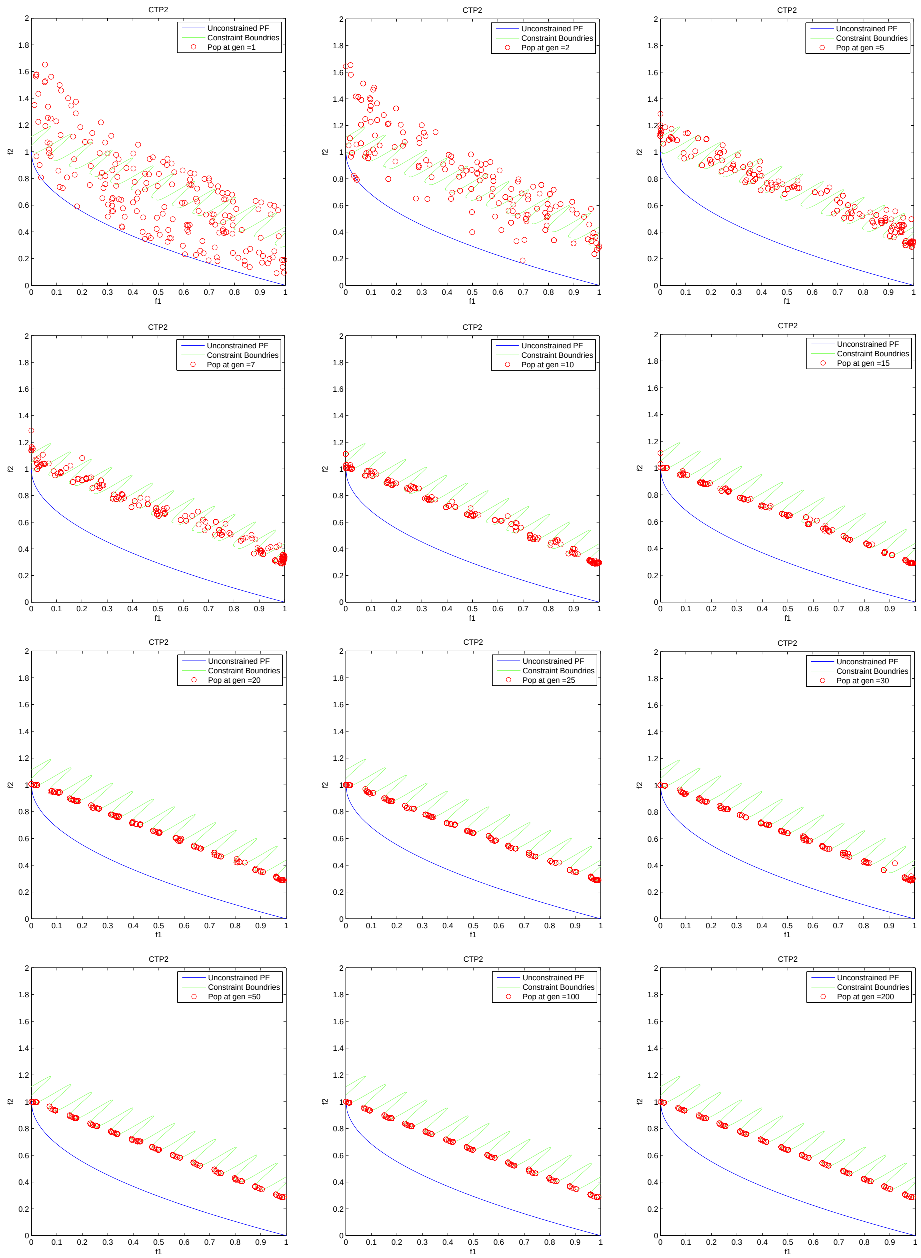


Fig. 9: Evolution of the CMOEA/D-DE-ATP population over generations for CTP2 test run.

H. Population Evolution in CMOEA/D-DE-ATP

Figures 9 and 10 show the progress of CMOEA/D-DE-ATP populations up to 200 generations for test instances CTP2 and CTP4. Both these figures demonstrate that how CMOEA/D-DE-ATP first converges the initial population to different disconnected constricted feasible regions near the PF in a few initial generations and then attains the Pareto-optimal solutions at the end of each one of them.

VI. Conclusions

A penalty function that penalizes infeasible solutions based on an adaptive threshold value has been introduced into the update and replacement scheme of CMOEA/D-DE. This resulted in a new algorithm, CMOEA/D-DE-ATP for CMOO. The performance of CMOEA/D-DE-ATP is tested on CTP-series test instances in terms of the HV-metric values.

From the experimental results in this paper, we can make the following conclusions.

- The comparison of CMOEA/D-DE-ATP with IDEA and NSGA-II unveiled that CMOEA/D-DE-ATP can find better and consistent statistics, in terms of the HV-metric, than the two contestant algorithms for all CTP-series test instances except CTP4.
- The study of the sensitivity of CMOEA/D-DE-ATP to the proposed penalty function and algorithmic param-

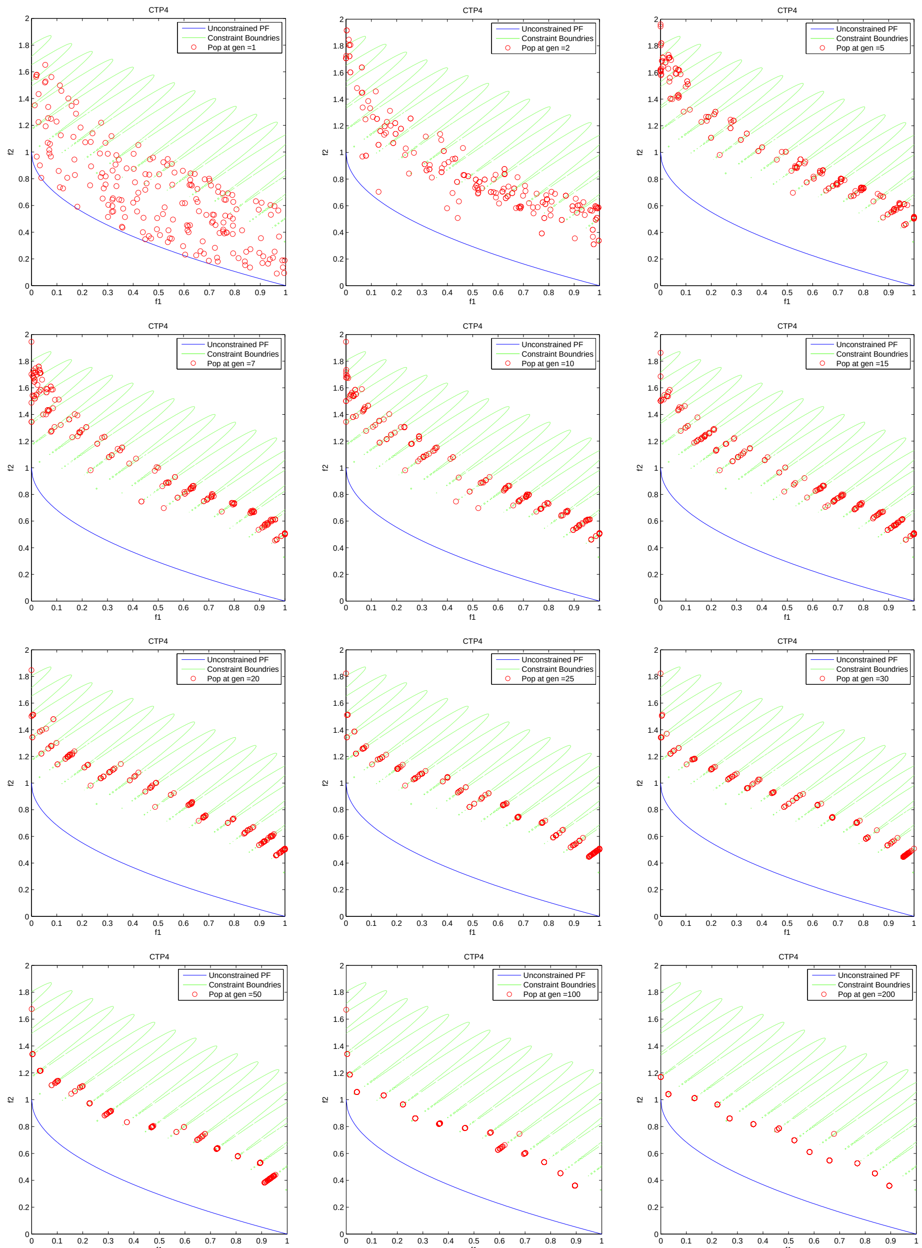


Fig. 10: Evolution of the CMOEA/D-DE-ATP population over generations for CTP4 test run.

eters disclosed that various parameters' settings are required for different test instances except s_1 and s_2 and CR and F.

- The proposed algorithm can find evenly distributed optimal solutions with a small population size, N.

REFERENCES

[1] M. A. Jan and Q. Zhang, "MOEA/D for constrained multiobjective optimization: Some preliminary experimental results," in *UK Workshop on Computational Intelligence (UKCI)*. IEEE, 2010, pp. 1–6.

[2] M. A. Jan, N. M. Tairan, R. A. Khanum, and W. K. Mashwani, "A new threshold based penalty function embedded MOEA/D," *International Journal of Advanced Computer Science and Applications(IJACSA)*, vol. 7, no. 2, pp. 647–655, 2016.

[3] K. Miettinen, *Nonlinear Multiobjective Optimization*. Kluwer Academic Publishers, 1999.

[4] K. Deb, *Multi-Objective Optimization using Evolutionary Algorithms*. John Wiley & Sons LTD, 2001.

[5] M. Gen and R. Cheng, "Interval Programming using Genetic Algorithms," in *Proceedings of the Sixth International Symposium on Robotics and Manufacturing*, Montpellier, France, 1996.

[6] E. M. Montes and C. A. Coello Coello, "A simple multimembered evolution strategy to solve constrained optimization problems: Smes," *IEEE Transactions on Evolutionary Computation*, vol. 9, no. 1, pp. 1–17, February 2005.

[7] T. Ray, H. K. Singh, A. Isaacs, and W. Smith, "Infeasibility driven evolutionary algorithm for constrained optimization," in *Constraint-Handling in Evolutionary Computation*, E. Mezura-Montes, Ed. Berlin: Springer. Studies in Computational Intelligence, Volume 198, 2009,

ch. 7, pp. 145–165, ISBN 978-3-642-00618-0.

[8] Y. G. Woldesenbet, G. G. Yen, and B. G. Tessema, "Constraint handling in multiobjective evolutionary optimization," *IEEE Transactions on Evolutionary Computation*, vol. 13, no. 3, June 2009.

[9] G. Yen, "An adaptive penalty function for handling constraint in multi-objective evolutionary optimization," *Constraint-Handling in Evolutionary Optimization*, pp. 121–143, 2009.

[10] M. R. Garey and D. S. Johnson, *Computers and Intractability: A Guide to the Theory of NP-Completeness*. W H Freeman and Co San Francisco, 1979.

[11] S. S. Rao, *Engineering Optimization*, 3rd ed. John Wiley & Sons, 1996.

[12] M. A. Jan and R. A. Khanum, "A study of two penalty-parameterless constraint handling techniques in the framework of MOEA/D," *Appl. Soft Comput.*, vol. 13, no. 1, pp. 128–148, 2013.

[13] H. Li and Q. Zhang, "Multiobjective Optimization Problems with Complicated Pareto Sets, MOEA/D and NSGA-II," *IEEE Transactions on Evolutionary Computation*, vol. 13, no. 2, pp. 284–302, April 2009.

[14] Q. Zhang and H. Li, "MOEA/D: A multiobjective evolutionary algorithm based on decomposition," *IEEE Transactions on Evolutionary Computation*, vol. 11, no. 6, pp. 712–731, 2007.

[15] K. Deb, A. Pratap, and T. Meyarivan, "Constrained test problems for multi-objective evolutionary optimization," in *First International Conference on Evolutionary Multi-Criterion Optimization (EMO 2001)*, ser. LNCS, vol. 1993. Zurich, Switzerland: Springer, 2001, pp. 284–298.

[16] Q. Zhang, W. Liu, and H. Li, "The Performance of a New Version of MOEA/D on CEC09 Unconstrained Mop Test Instances," in *Special Session on Performance Assessment of Multiobjective Optimization Algorithms/CEC 09 MOEA Competition*, Norway, 18-21 May 2009.

[17] K. Deb, A. Pratap, S. Agarwal, and T. Meyarivan, "A fast and elitist multiobjective genetic algorithm: NSGA-II," *IEEE Transactions on Evolutionary Computation*, vol. 6, no. 2, pp. 182–197, April 2002.

[18] K. M. Miettinen, *Nonlinear Multiobjective Optimization.* Kluwer Academic Publishers, 1999.

[19] K. Price, R. M. Storn, and J. A. Lampinen, *Differential Evolution: A Practical Approach to Global Optimization*, ser. Natural Computing. Secaucus, NJ, USA: Springer-Verlag, 2005.

[20] D. Van Veldhuizen, "Multiobjective evolutionary algorithms: classifications, analyses, and new innovations," in *Evolutionary Computation*. Citeseer, 1999.

[21] E. Zitzler and L. Thiele, "Multiobjective optimization using evolutionary algorithmsa comparative case study," in *Parallel Problem Solving from NaturePPSN V*. Springer, 1998, pp. 292–301.

Scheduling on Heterogeneous Multi-core Processors Using Stable Matching Algorithm

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***Abstract*—Heterogeneous Multi-core Processors (HMP) are better to schedule jobs as compare to homogenous multi-core processors. There are two main factors associated while analyzing both architectures i.e. performance and power consumption. HMP incorporates cores of various types or complexities in a solitary chip. Hence, HMP is capable to address both throughput and productivity for different workloads by coordinating execution assets to the needs of every application. The primary objective of this study is to improve the dynamic selection of the processor core to fulfill the power and performance requirements using a task scheduler. In the proposed solution, there will be dynamic priority lists for tasks and available cores. The tasks to core mapping is performed on the basis of priorities of the tasks and cores.**

***Index Terms*—Heterogeneous, Performance, Scheduling, Multi-core processors, Stable matching**

I. Introduction

HMP is becoming mainstream because it has potential to reduce the power consumption and improve the performance than homogeneous core processors. In HMP architecture, individual cores have different computational capabilities as shown in Figure 1. Since, HMP architecture consists of a combination of small and big cores, it can perform better in larger computations [1]. HMP architectures opens up new challenges and possibilities for thread scheduling, load balancing and energy management. The performance and energy efficiency can be achived with HMP by allowing each job to run on core type which suits the most [2]. Furthermore, HMP can adequately reduce processor power utilization and can significantly build the performance and speed of execution. The HMP decreases the frequency of the processors which reduce the temperature of the system. In these processors, the amount of parallelism increased because of simultaneous execution of instructions on individual cores. The MB scheduler can dynamically select the relevant core to fulfill the power and performance requirements [3].

HMP can be characterized into two groups i.e. ”performance asymmetry” and ”functional asymmetry”. In functional asymmetry, architecture cores have distinctive or overlapping instruction sets while in performance asymmetry, architecture cores vary in performance because of the difference in frequency and architecture [4]. Additionally, HMP architecture is more attractive and an alternative design as compare to homogeneous designs. HMP has a unique benefit in maximizing both execution performance and throughput. Although, the existing multi-core processors are mostly homogeneous which leads to an unpreventable problem i.e. reproducing smaller cores losses the throughput of the high-complexity single-threaded applications, though duplicating bigger cores yields the execution proficiency of the low-complexity low-priority threads. However, HMP incorporates cores of various types or complexities in a solitary chip, and hence it is capable to address both throughput and productivity for different workloads by coordinating execution assets to every application’s needs [5].

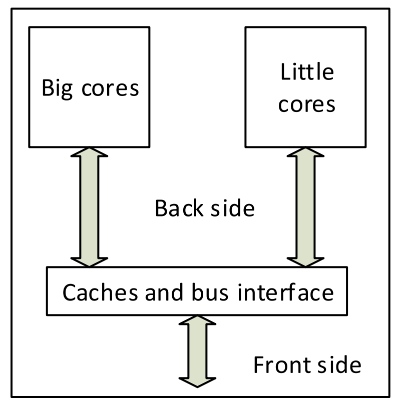

Fig. 1. HMP architecture

In future, many core and multi-core processors will comprise of heterogeneous cores that might expose a typical Instruction Set Architecture (ISA) but vary in features e.g. performance, size and energy utilization. A solitary processor will contain numerous small cores and a few bigger complex cores. Simple cores will remain scalar in order and may have a small cache and lower clock frequency. Complex cores will be super-scalar and might be outfitted with high performance and consume more power. Heterogeneous architectures are inspired by their capability to accomplish a higher execution per Watt than homogeneous architectures [6].

To understand this architecture, operating systems must be aware with heterogeneity. That is, it must allocate applications to keep running on proper cores. Consider a workload comprising of a logical application portrayed by Instruction Level Parallelism (ILP), and a memory-bound employment, for example, preparing exchange in a database. The logical application will be executing essentially quicker on an complex cores, though the database application may indicate equivalent execution on both sorts of cores. In this case, assigning tasks to cores that are fitting for them will accomplish huge power saving.

Having the capacity to make intelligent decisions at run time is the objective of heterogeneity scheduling. While heterogeneity scheduling algorithms were proposed in the past which were focused at small scale multi-core frameworks. If increase the number of chips, dynamic checking might become excessively tedious and impractical. HMP gives another way of various computing abilities. When the processor performance and speed increases there are many challenges may rise e.g. heat dissipation and power utilization.

The primary focus of this paper is to improve the dynamic selection of the most appropriate processor core to fulfill the power and performance requirements using a task scheduler.

II. Literature Review

Previous work on HMP architecture insights the importance of heterogeneity for both performance and power efficiency. In a study [7], authors proposed and evaluated a single ISA HMP architectures to reduce processor power utilization first time. In this paper, authors exploited the time varying behavior of applications and power consumption using thread migration approach at run time. The design of this approach integrates heterogeneous cores indicating different facts in the performance/power design space during the execution of an application. The system software chooses the most appropriate core dynamically to meet the particular performance and power needs.

In another relevant study [8], authors proposed scheduler for different applications to schedule on different cores in single ISA HMP designs. In this study, authors have demonstrated that by scheduling applications on more power efficient HMP, throughput for static workloads will be increased. On the other hand, it reduces the response time for dynamic applications. Furthermore in [9], explored the standards to design single-ISA HMP. In this study, authors just concentrated on framework throughput and do not consider per-program execution.

Furthermore in [4], authors proposed a bias scheduling approach for performance asymmetric heterogeneous with different micro architecture cores. They identified the key metrics that distinguish the possible benefits of scheduling an application on a big core rather than on a small core and according to the core type that outfits the resource requirements of the application. Bias scheduler is very flexible and can be implemented on any scheduler. In this paper, authors have implemented bias scheduler on the top of Linux Scheduler and concluded that performance can be improved significantly. Bias scheduler monitors the application at run time and match the threads according to the core types to increase the throughput of the system.

Moreover in [6], authors proposed an approach that does not depend on dynamic performance monitoring. In this approach, the required information to make an appropriate decision for core assignments is provided with the application itself. The provided information is used as an architectural signature of the running application which composed of certain architecture independent features. These signatures can be generated offline and embedded into the binary of an application. Further, authors demonstrated prediction the sensitivity of an application and evaluated a scheduler model that uses these architectural signatures for scheduling on a heterogeneous system with various clock frequencies cores.

Further, authors in [2] proposed a lucky scheduling algorithm to schedule threads on HMP for energy efficiency and performance boost up. In lucky scheduling algorithm each task receives a dynamic number of tickets. The tickets will determine the switching of running tasks between small and big cores. Moreover, the idea of lucky scheduling algorithm is derived from a lottery scheduler system [10]. Additionally, the lottery scheduler system is used to select the lottery tickets dynamically.

In another relevant studies [11], [12], sampling based scheduling is applied using direct approach to determine the best scheduling policy on a HMP. In sampling based scheduling, samples of different workload are mapping to core dynamically at runtime. After that best mapping is selecting with respect to performance. Further, sampling based scheduling periodically migrate the workload between different cores. By using sampling based approaches performance is improving while, on the other hand it also introduces migration overhead. Moreover, migration overhead is directly proportional to number of cores.

To overcome the migration between different type of cores, authors proposed a Performance Impact Estimation (PIE) approach [13]. In this study PIE mechanism is used to predict best performing workload to core mapping. PIE collects Cycles per Instruction (CPI) stack, ILP, number of misses, latency per miss and the number of simultaneously outstanding misses to make prediction. On the basis of collected information it estimates the performance if the workload is to run on a different core types. Dynamic PIE performs scheduling at runtime.

III. Proposed Methodology

The proposed solution is using stable matching algorithm to assign the tasks to suitable cores. In this approach both cores and tasks have their own priority lists as shown in Table I and Table II. The proposed scheduler keeps track of the priorities and availability of cores. At the time of job mapping to core, the algorithm selects the best possible pair of task and core. Steps of the proposed algorithm is given below in Figure 2 and architecture diagram in Figure 3. The algorithm takes priority lists as an input in step 1. In step 2, set cores free to fetch

TABLE I
PRIORITY LIST OF EACH TASK

	Task 1	Task 2	Task 3
Priority 1	Core - SISD	Core - MIMD	Core - SIMD
Priority 2	Core - SIMD	Core - MISD	Core - SISD
Priority 3	Core - MIMD	Core - SISD	Core - MISD

TABLE II
PRIORITY LIST OF EACH CORE

	Core 1	Core 2	Core 3
Priority 1	Task - SISD	Task - MIMD	Task - SIMD
Priority 2	Task - SIMD	Task - MISD	Task - SISD
Priority 3	Task - MIMD	Task - SISD	Task - MISD

```
1: Input: priority lists of tasks and cores
2: Initialize each core to be free.
3: while (some core is free and hasn't assigned to every task)
   {
4:       Choose such a core c
5:       t = 1st core on c's list to whom c has not yet assigned
6:       if (t is not assigned)
7:                choose c and t to be assigned
8:       else if (t prefers c to its assigned task c' and c' is free )
9:                choose c and t to be assigned, and c' to be free
10       else
11                t rejects c
   }
12: Output: stable tasks to cores mapping
```

Fig. 2. Stable matching algorithm to map tasks to cores

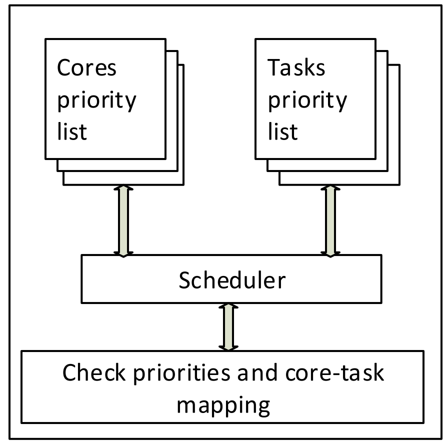

Fig. 3. Proposed scheduler architecture

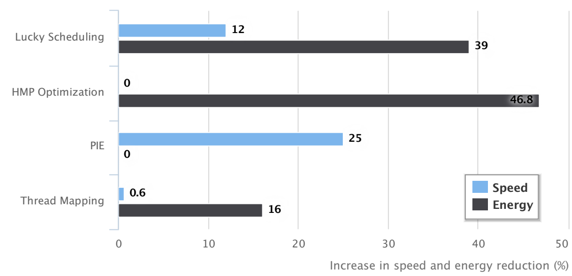

Fig. 4. Dynamic approaches comparison

jobs according to their priorities. The while loop in step 3 will execute until until all cores and task mapped. Further, in step 4, select a core and fetch a task for execution in step 5. In step 6, 8, 10 if else conditions are checked. If condition is true and task is not assigned to other core, the task t will be assigned to that core in step 7. Otherwise, task is not executing and prefers other core c on assigned core c', task t will be assigned to core c and c' core will set free in step 9. If priorities of both task and core do not match task will rejects the core.

IV. PERFORMANCE EVALUATION OF EXISTING SYSTEMS

The algorithms discussed in Section II have demonstrated that the performance on HMP is increased but they have a number of drawbacks. If the number of core types is large, monitoring of a thread or subsets of threads become infeasible. The operating system needs to track a lot of information and performance will be affected. Also, the amount of time for monitoring the thread will increase. Table III shows the comparison of different schedulers and experimental results of existing approaches and Figure 4 shows the comparison of different dynamic approaches. In [2], authors have used one core of speed 3.2 GHz and three cores of speed 0.8 GHz. The L3 cache of size 6MB shared between cores. By using luck scheduler algorithms authors achieved 12% inc rease in speed and energy consumption is reduced by 39%. Further, in [6], authors used static approach to schedule jobs on different cores. In this study authors have categorized the experiments into two groups i.e "high heterogeneous workload" and "typical workload". In high heterogeneous workload, authors used two cores of speed 2.0 GHz and other two cores of speed 3.0 GHz. With this approach, throughput of the HMP is increased by 4.7%. While in typical workload, authors used all four cores of different speed such as 2.0 GHz, 2.33 GHz, 2.67 GHz and 3.0 GHz and achieved 2.7% increase in speed of task completion.

Moreover, in [9], authors focused on energy consumption reduction by scheduling task statically and dynamically. In static approach, authors used 2 to 8 cores of speed 2.1 GHz and reduced the 31.9% power consumption with 2.6% performance loss. While, in dynamic approach authors have used L2 cache of size 3.5 MB additionally and saved 46.8% energy with 10% performance loss.

Further, authors in [13], performed experiments using both static and dynamic approaches. In dynamic approach authors increased the speed by 25% with four big cores of speed 2.1 GHz, L1 cache of 32 KB, L2 cache of 256 KB and L3 cache of size 4 MB. While, in static approach, they used the same cache with four small cores of speed 2.1 GHz and reduced the

TABLE III
COMPARISON OF JOB SCHEDULERS IN HMP.

ID	Scheduler	Clock Speed (GHz)	No. of Cores	Cache	Speed (%)	Energy (%)	Perf. Loss(%)
[2]	Dynamic	3.2x1, 0.8x3	4	L3(6MB)	12	39	-
[6]	Static	2.0x2, 3.0x2	4	-	4.7	-	-
	Static	2.2, 2.33, 2.67, 3.0	4	-	2.7	-	-
[9]	Static	2.1	2 to 8	-	-	31.9	2.6
	Dynamic	2.1	2 to 8	L2(3.5MB)	-	46.8	10
[13]	Dynamic	2.0	4 big	L1(32KB), L2(256KB), L3(4MB)	25	-	-
	Static	2.0	4 small	L1(32KB), L2(256KB), L3(4MB)	47	-	-
[14]	Dynamic	2.5	64 to 1024	L2(256KB)	0.6	16	-

47% task completion time. Furthermore, in [14], authors used dynamic approach with 64 to 1024 cores of speed 2.5 GHz and L2 cache of size 256 KB. They gained the speed of 0.6% and saved 16% energy consumption.

The above discussion shows the static and dynamic approaches to schedule jobs on HMP. The dynamic approaches have proved to be beneficial but due to the overhead between switching cores they yield a low performance. On the other hand, static approaches do not have dynamic scheduling, however, they use a predefined allocation of cores. The proposed approach in this study provides a solution to both of these issues. It dynamically takes care of priorities of cores and available tasks. Afterward, it maps each task to its preferred core which in turn reduces the switching overhead that will increase the throughput of the HMP and provide an energy efficient approach to process computation intensive tasks.

V. CONCLUSION AND FUTURE WORK

The HMP design is vast and there are many ultimate design choices to be made. The type of cores vary from simple in order to complex out of order cores. There are many possible configurations of core types and number of cores. Therefore, job to core mapping is both challenging and important for HMP to achieve optimum performance. Previous studies focused on static and dynamic techniques for scheduling tasks on different cores as presented in the above discourse. The main objective of scheduling tasks by employing these techniques was to save energy and enhance throughput. However, there were associated challenges related to switching tasks among cores such migrating overhead.

In the proposed solution, there will be dynamic priority lists for tasks and available cores. Here, each core will be assigned to that task which is at the 1st priority in core's list. If 1st priority task is not available then next task in the priority list will be assigned and so on. By following this approach, task execution and processor task mapping will yield reduction in task completion time. Thereby, task switching and migrating overhead will be optimized as well. In future, the main objective is to implement and simulate the proposed technique to evaluate its results in real time environment.

REFERENCES

[1] Q. Chen, Y. Chen, Z. Huang, and M. Guo, "Wats: Workload-aware task scheduling in asymmetric multi-core architectures," in *26th International Parallel & Distributed Processing Symposium (IPDPS)*. IEEE, 2012, pp. 249–260.

[2] V. Petrucci, O. Loques, and D. Mosse, "Lucky scheduling for energy-efficient heterogeneous multi-core systems," in *Presented as part of the 2012 Workshop on Power-Aware Computing and Systems*, 2012.

[3] L. A. Priyadarshni, "Heterogeneous multi core processors for improving the efficiency of market basket analysis algorithm in data mining," *CoRR*, vol. abs/1409.6679, 2014.

[4] D. Koufaty, D. Reddy, and S. Hahn, "Bias scheduling in heterogeneous multi-core architectures," in *Proceedings of the 5th European conference on Computer systems*. ACM, 2010, pp. 125–138.

[5] J. Chen and L. K. John, "Efficient program scheduling for heterogeneous multi-core processors," in *Proceedings of the 46th Annual Design Automation Conference*. ACM, 2009, pp. 927–930.

[6] D. Shelepov and A. Fedorova, "Scheduling on heterogeneous multicore processors using architectural signatures," in *In Proceedings of the Workshop on the Interaction between Operating Systems and Computer Architecture, in conjunction with the 35th International Symposium on Computer Architecture*, 2008.

[7] R. Kumar, K. I. Farkas, N. P. Jouppi, P. Ranganathan, and D. M. Tullsen, "Single-isa heterogeneous multi-core architectures: The potential for processor power reduction," in *Microarchitecture, 2003. MICRO-36. Proceedings. 36th Annual IEEE/ACM International Symposium on*. IEEE, 2003, pp. 81–92.

[8] R. Kumar, D. M. Tullsen, P. Ranganathan, N. P. Jouppi, and K. I. Farkas, "Single-isa heterogeneous multi-core architectures for multithreaded workload performance," *ACM SIGARCH Computer Architecture News*, vol. 32, no. 2, p. 64, 2004.

[9] R. Kumar, D. M. Tullsen, and N. P. Jouppi, "Core architecture optimization for heterogeneous chip multiprocessors," in *Proceedings of the 15th international conference on Parallel architectures and compilation techniques*. ACM, 2006, pp. 23–32.

[10] C. A. Waldspurger and W. E. Weihl, "Lottery scheduling: Flexible proportional-share resource management," in *Proceedings of the 1st USENIX conference on Operating Systems Design and Implementation*. USENIX Association, 1994, p. 1.

[11] M. Becchi and P. Crowley, "Dynamic thread assignment on heterogeneous multiprocessor architectures," in *Proceedings of the 3rd conference on Computing frontiers*. ACM, 2006, pp. 29–40.

[12] J. A. Winter, D. H. Albonesi, and C. A. Shoemaker, "Scalable thread scheduling and global power management for heterogeneous many-core architectures," in *Proceedings of the 19th international conference on Parallel architectures and compilation techniques*. ACM, 2010, pp. 29–40.

[13] K. Van Craeynest, A. Jaleel, L. Eeckhout, P. Narvaez, and J. Emer, "Scheduling heterogeneous multi-cores through performance impact estimation (PIE)," in *ACM SIGARCH Computer Architecture News*, vol. 40, no. 3. IEEE Computer Society, 2012, pp. 213–224.

[14] G. Liu, J. Park, and D. Marculescu, "Dynamic thread mapping for high-performance, power-efficient heterogeneous many-core systems," in *IEEEE 31st International Conference on Computer Design (ICCD)*. IEEE, 2013, pp. 54–61.

Determining adaptive thresholds for image segmentation for a license plate recognition system

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***Abstract*—A vehicle license plate recognition (LPR) system is useful to many applications, such as entrance admission, security, parking control, airport and cargo, traffic and speed control. This paper describe an adaptive threshold for image segmentation applied to a system for Malaysian intelligent license plate recognition (MyiLPR). Due to the different types of license plates used, the requirements of an automatic LPR system are rather different for each country. Upon receiving the input car image, this system (MyiLPR) detects and segments the license plate based on proposed adaptive threshold via image and blob histogram, and blob agglomeration, and finally, it extracts geometric character features and classifies them using neural network. The use of the proposed adaptive threshold increased the detection, segmentation and recognition rate to 99%, 94.98% and 90% correspondingly, from 95%, 78.27% and 71.08% obtained with the fixed threshold used in the originally proposed system.**

Keywords*—adaptive threshold; image segmentation; license plate recognition; neural network; computer surveillance;

I. Introduction

Automatic license plate recognition (LPR) is an important research subject due to its many applications. For local authorities, LPR is required for the purposes of law enforcement, border protection, vehicle thefts, automatic toll collection and perhaps traffic control. For others, automatic LPR can be applied to gain access into housing areas, automatic parking control and as a marketing tool in large shopping complexes, as well as for surveillance.

LPR consists of five major steps: image capturing, image processing, segmentation, feature extraction and pattern classification. Usually, an LPR system includes targeted functions and specifications, such as a fast alphanumeric character recognition system. In addition, 24 hours non-stop operation is expected and the ability to issue alarm messages which are sent out after the recognition phase.

An important issue in image preprocessing for a real time application, like license plate recognition, is the selection of the best threshold value for image binarization. Choosing the wrong threshold can cause failure in either the detection or the segmentation process, as the thresholded image could either totally hide the required objects or cause distraction in the region of interest due to variable illumination. Several researchers have proposed different ways for selecting the best threshold. For example Yoshimori *et al.* [1] used a real-coded genetic algorithm and a so called hereditary threshold determination method, Kim *et al.* [2] used an enhanced neural network, and Lee *et al.* [3] used adaptive local binarization. Another technique referred to as the Otsu automatic threshold [4] has also been extensively used in LPR and other applications.

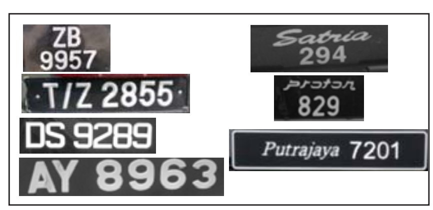


Fig. 1: (a) Samples of common license plates and (b) Samples of special license plates in Malaysia.

In Malaysia, perhaps 95% of the vehicles' license plates are in the form of a single or a double line with normal fonts (Figure 1(a)). The other 5% are made of special fonts, such as those shown in Figure 1(b). The halo or illumination and unstandardized Malaysian plate issues have made license plate recognition continues to face big challenges [5]–[9]. On 20th January 2015, the signing ceremony for memorandum of agreement (MoA) between UKM Tech (M) Sdn. Bhd. and Synergy Saver (M) Sdn. Bhd. was held successfully. According to Synergy Saver CEO Mr. Shariffpudin Basiron;

> Up to date, the license plate recognition technology for Malaysian license plate cases are still an open issue. Our company purchased and tested several existing LPR products, yet we failed to achieve high accuracy rate. It is due to lack of enforcement towards unstandardized license plate format practice from road user. We believed that a collaboration between researchers (UKM) and industry will be able to solve the issues regarding Malaysia license plate recognition.

The objective of this paper is to propose an adaptive thresholding method for thresholding both the number plate from the car image and the individual characters within the number plate region, and to compare its results with those obtained by a fixed threshold, another state of the art thresholding method, as well as Otsu's automatic thresholding method, in relation to a Malaysian license plate recognition system.

This paper is organized as follows. Section II reviews the state of the art in automatic threshold selection. Section III explains the proposed method and Section IV presents and analyses the experimental results. Finally, conclusions are presented in Section V.

II. State of the Art

Thresholding is a straightforward technique in transforming a gray scale image into a binary image that can facilitate the segmentation process. If h, is the input image, the value of the output image, $\wp$, at position (x,y), given a threshold Ω, is:

$$\wp(x,y) = \begin{cases} 1 & \text{if} \quad h(x,y) \geq \Omega, \\ 0 & \text{else} \quad h(x,y) < \Omega. \end{cases} \tag{1}$$

Recent most popular global binarization used on license plate recognition is Otsu thresholding method [10]–[12] for its simplicity and fast performance. In addition, one of the most recently introduced methods for threshold determination known as adaptive contrast is also based on Otsu method [13]. Meanwhile, Niblacks and Sauvolas methods become an alternative to solve shadows and illumination problem [14], [15] on license plate images. Global binarization methods are dependent on distinct image foreground and background such that the preprocessing and post-processing on binarization can contribute towards optimal results. Some recent work such deblurring [16], image filtering algorithms [17], [18] and super-resolution [19] are good example for preprocessing. Although post-processing approach are not popular compared to preprocessing, some recent work such dirt effect elimination [20] show decent result in character segmentation.

One of the most recent introduced methods for threshold determination is based on the local entropy [21]. This approach has been widely used for measuring the local information content or uncertainty and the information content of a probability distribution [22], [23]. First, the co-occurrence matrix of the image is constructed considering pairs of pixels that are either one below the other or one next to the other. For N grey level values, the co-occurrence matrix is $N \times N$ in size. Selecting a threshold value M divides the matrix into four quadrants (see Figure 2). The entropy of each quadrant can be computed and

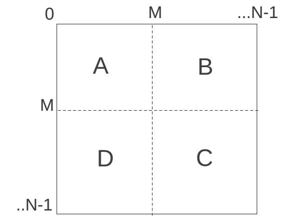


Fig. 2: A threshold M partitions the co-occurrence matrix into four quadrants. The maximum entropy threshold maximises the entropy in quadrants A and C. For a bright object, quadrant C corresponds to pairs of object pixels.

the threshold that maximises the sum of the entropies of the quadrants that correspond to the object and the background is selected. If p_{ij} is an element of the co-occurrence matrix, we normalise it so that the sum of all values inside each quadrant is 1.

Assuming a bright object, the elements of the matrix in quadrant C (see figure 2) are divided by P_O, and the elements of the matrix in quadrant A are divided by P_B,

$$P^O_{ij} \equiv \frac{p_{ij}}{P_O} \qquad P^B_{ij} \equiv \frac{p_{ij}}{P_B}, \tag{2}$$

where,

$$P_O \equiv \sum_{i=M+1}^{N-1} \sum_{j=M+1}^{N-1} p_{ij} \qquad P_B \equiv \sum_{i=0}^{M} \sum_{j=0}^{M} p_{ij}. \tag{3}$$

Then the Shanon entropy, $E_O(M)$ and $E_B(M)$ for object and background respectively, is:

$$E_O(M) = -\frac{1}{2} \sum_{i=0}^{M} \sum_{j=0}^{M} P^O_{ij} \log_2 P^O_{ij}, \tag{4}$$

$$E_B(M) = -\frac{1}{2} \sum_{i=M+1}^{N-1} \sum_{j=M+1}^{N-1} P^B_{ij} \log_2 P^B_{ij} \tag{5}$$

The threshold that maximises the total entropy,

$$E_T(M) \equiv E_O(M) + E_B(M) \tag{6}$$

is considered to be the optimal threshold. Fuzzy [24], excess [25] and honey bee optimization [26] has been incorporated into the method of threshold identification. The local entropy computation time is similar to that for Otsu's automatic threshold determination method. In this paper, we shall compare the results of the entropy-based and Otsu's methods with the results of a heuristic method presented in the next section for an LPR system.

In some cases, a single threshold is not applicable for global segmentation. Hence, multiple threshold values are identified to segment an image globally. A statistical recursive approach proposed in [27] calculates first the mean μ and standard deviation σ of the image. Two thresholds are then defined:

$$\text{S1} = \mu + \kappa_1 \times \sigma \tag{7}$$

$$\text{S2} = \mu - \kappa_2 \times \sigma \tag{8}$$

where κ_1 and κ_2 are free parameters.

Pixels with value below the low threshold constitute one segment and pixels with value above the high threshold another segment. In the output image, each such pixels is assigned the average grey value of the segment to which it belongs. Pixels with values in between the two thresholds are thresholded further, in the same way, by calculating their mean and standard deviation, to form two new segments in the output image, carrying grey values equal to their respective means, and a central segment, which may be further subdivided in the same way. The method is repeated recursively, until the central segment diminishes, or a prespecified number of thresholds has been defined, or the Peak Signal to Noise Ratio (PSNR) reaches a certain value. PSNR computes noise introduced in the image by replacing the true grey values of the pixels with the average grey values of the segments to which they belong:

$$PSNR = 20 \times \log_{10}\left(\frac{255}{RMSE}\right), \tag{9}$$

where

$$RMSE = \sqrt{\frac{1}{S \times T}\sum_{x=1}^{S}\sum_{y=1}^{T}[\wp(x,y) - h(x,y)]^2} \tag{10}$$

III. The Proposed Method

The proposed thresholding method consists of three steps: (1) identify the type of image according to its histogram; (2) calculate blob distributions for various threshold values and (3) select threshold value(s) based on a simple heuristic decision rule. Each of the steps is explained next.

1) Identify the type of image according to its histogram: At this stage the contrast of the image is assessed and the image is categorised as dark, of medium brightness or bright, according to the shape of its histogram. We simply partition the 8-bit image into three levels by dividing 256 into 3 predetermined categories and sum those pixel frequencies for each category. Hence, we used the following heuristic rules to assess the shape of the histogram of the image:

$$\Theta = \begin{cases} dark & \text{if } \left(\sum_{g=0}^{g=85}\rho_g \geq \sum_{g=86}^{g=170}\rho_g\right) \wedge \left(\sum_{g=0}^{g=85}\rho_g \geq \sum_{g=171}^{g=255}\rho_g\right), \\ medium & \text{if } \left(\sum_{g=86}^{g=170}\rho_g \geq \sum_{0}^{g=85}\rho_g\right) \wedge \left(\sum_{g=86}^{g=170}\rho_g \geq \sum_{g=171}^{g=255}\rho_g\right), \\ bright & \text{if } \left(\sum_{g=171}^{g=255}\rho_g \geq \sum_{g=0}^{g=85}\rho_g\right) \wedge \left(\sum_{g=171}^{g=255}\rho_g \geq \sum_{g=86}^{g=170}\rho_g\right). \end{cases} \tag{11}$$

Here ρ_g is the number of pixels in the image with grey value g and the image is assumed to be an 8-bit grey image.The histograms of images 'ADG676', 'ACP92' and 'ACN65' (Figure 3) are shown in Figure 4.

2) Calculation of blob distributions for various threshold values: We transform source image into binary images using as a series of 25 thresholds, starting from threshold 0 and increasing its value in steps of 10. For each threshold, the number of the connected components created is identified. In Figure 5 we plot the number of the connected components identified this way for each of the example images of Figure 3, versus the threshold used. We then consider the thresholds that created the peaks in these graphs. This sub-process determines the peak as the adaptive thresholds as the more number of blobs gained, therefore the higher potential for the important objects (foreground) to be segmented or separated from the background of an image.

3) Selection of the thresholds: Some preliminary experiments showed that if the type of image is of 'medium brightness', a threshold of 130 sometimes leads to good results. So for this type of image, threshold 130 is always used in addition to the other thresholds identified as explained next. For all types of image, all thresholds that correspond to the peaks of the blob distributions had to be used. Open circles identify the peaks of the blob distributions as in in Figure 5, and dictates in a listing as in Table I, for the example images of Figure 3. TThese thresholds produce images as shown in Figure 6.

We notice that in Figure 6(a) and 6(c), which correspond to the images in the category of 'dark', and 'bright', respectively, there is a clear character separation in the number plate for thresholds $\Omega_{Select} = 40$ for the 'ACN65' image, and $\Omega_{Select} = 60, 90, 110, 170$ for the 'ADG676' image. So, in the subsequent steps, the thresholds selected at this stage will be used to identify all white blobs. The flow chart of the proposed method for threshold selection is shown in Figure 7.

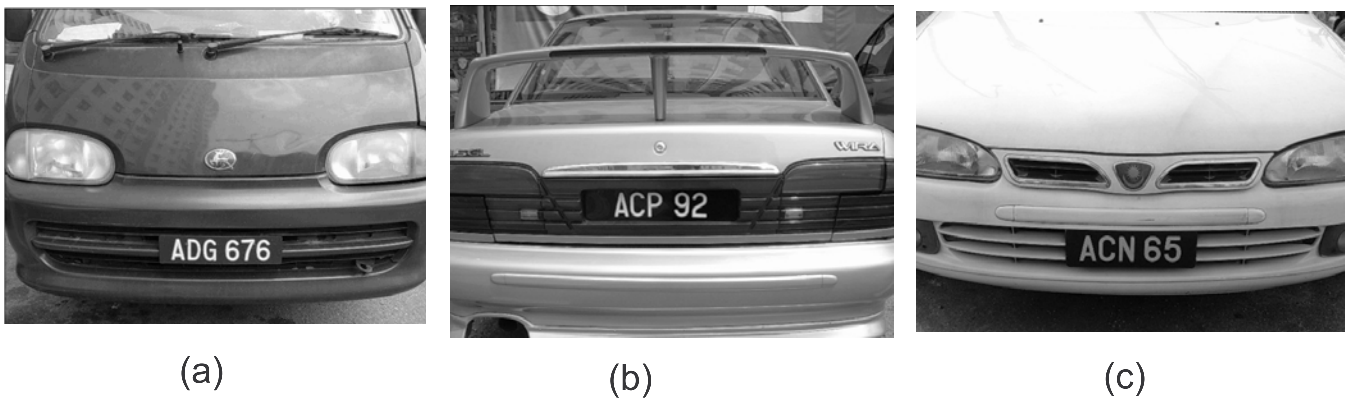


Fig. 3: Examples of (a) ‘dark’, (b) ‘medium’ and (c) ‘bright’ license plate images.

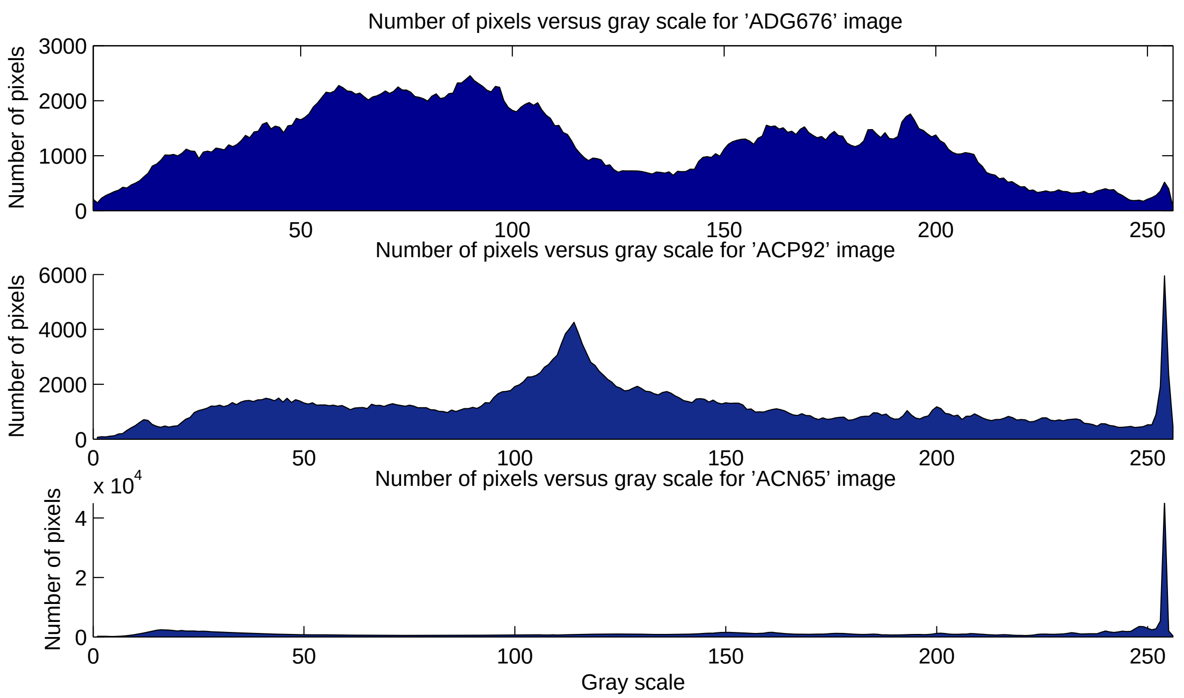
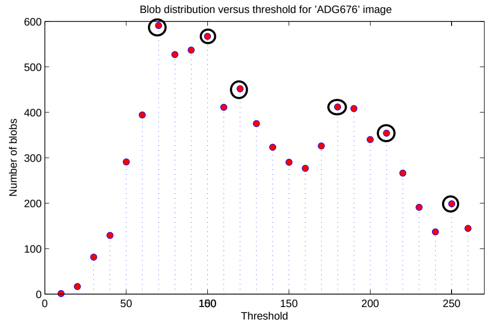
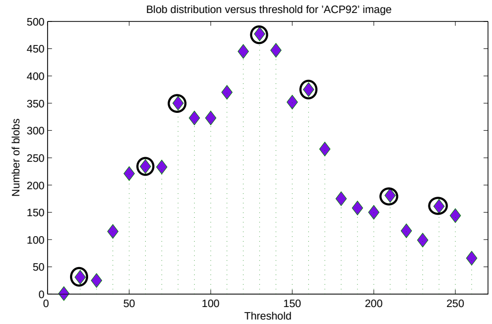


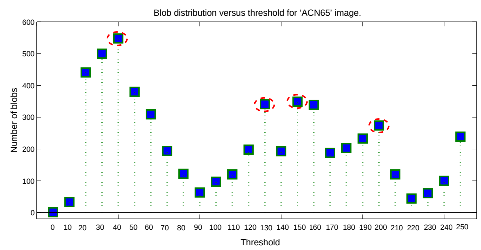
Fig. 4: The histogram distribution, $\rho_{(0,1,\ldots,255)}$, for the ‘ADG676’, ‘ACP92’ and ‘ACN65’ car image from top to bottom, respectively.



(a)



(b)

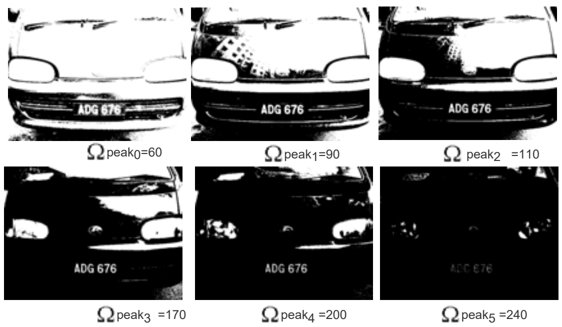


(c)

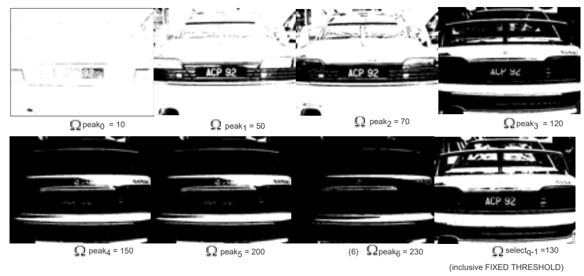
Fig. 5: Each threshold used for (a) ADG676, (b) ACP92, and (c) ACN65 images created a distributions for number of blobs. Identified circles represent the local maxima in each distribution.

TABLE I: The thresholds that create the peaks in the distributions of Figure 5.

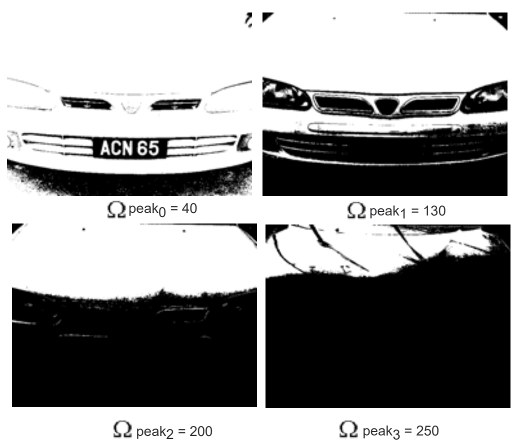
Peak index, p	Peak threshold values, $\Omega_{Peak_{(0,1,\ldots,p-1)}}$ ADG676	ACP92	ACN65
0	60	10	40
1	90	50	130
2	110	70	200
3	170	120	250
4	200	150	-
5	240	200	-
6	-	230	-



(a)



(b)



(c)

Fig. 6: Examples of the thresholding results using as thresholds the grey values that correspond to the peaks of the graphs in Figure 5 for (a) ‘ADG676’, (b) ‘ACP92’ (also includes the result for the 130 threshold value), and (c) ‘ACN65’, respectively.

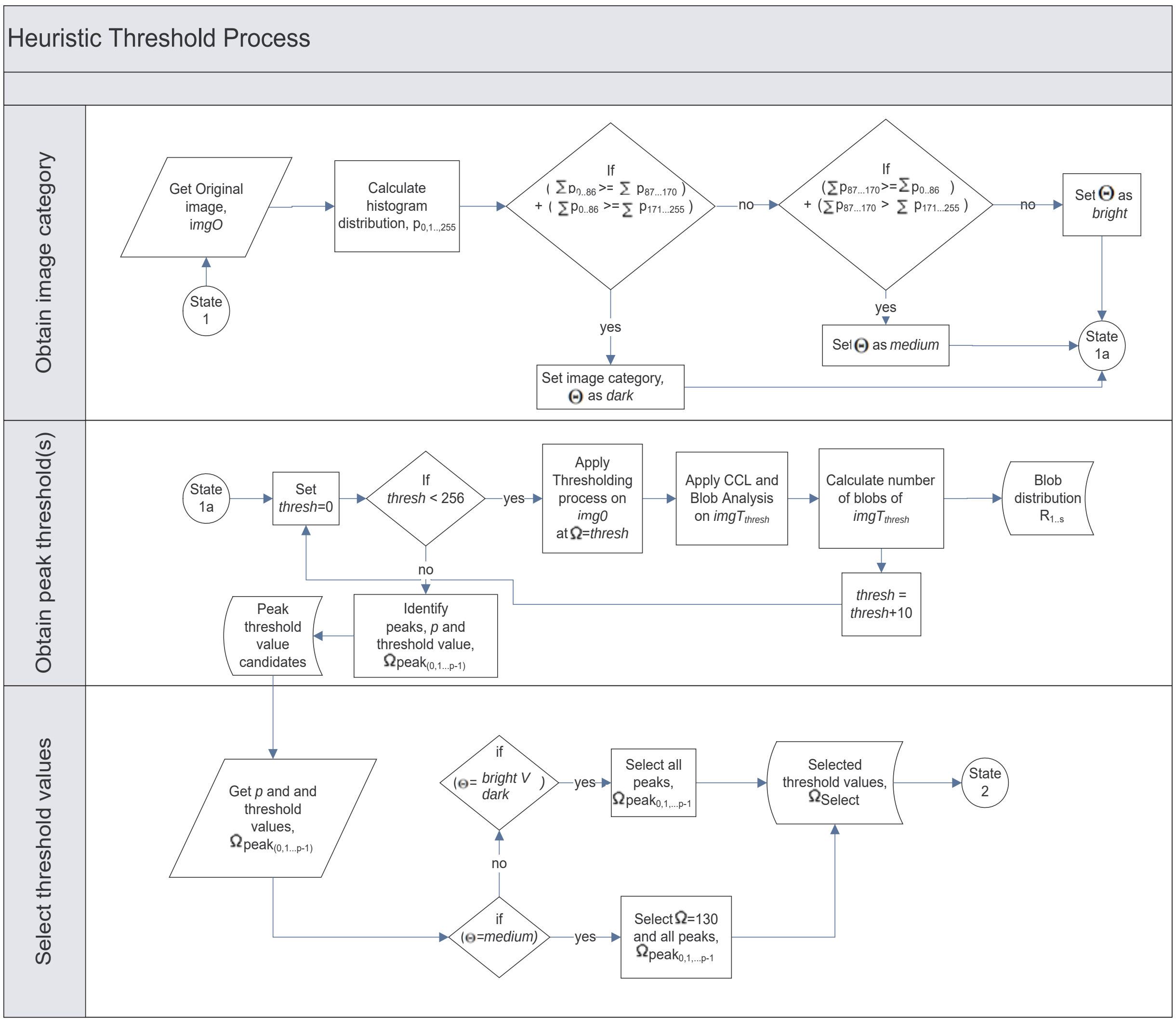


Fig. 7: The flow chart of the proposed threshold selection process.

A. Blob Agglomeration

Further processing will only consider all white blobs identified by the selected threshold applied to an image. Hence, the minimum enclosing rectangle will represent each blob. Eventually, we remove noise by considering each blobs' height and width at a certain size. In an LPR operational system, the scale of the images captured is assumed to be known. So, these size thresholds may easily be selected and fixed from the beginning. In our case, blobs narrower than 5 pixels and shorter than 15 pixels were treated as due to noise and removed. Then, the agglomeration process selects the remaining blobs into several clusters, starting from the top left, corner of the top left blob and agglomerates blobs that did not differ very much in their vertical position in the image will build up the cluster, as well as in height. In particular, if $Y_{current}$ is the vertical coordinate of the top left corner of the minimum enclosing box of the cluster, and $\breve{Y}$ is the vertical coordinate of the top left corner of a blob, and $H_{current}$ is the height of the minimum enclosing box of the cluster, the new blob is added to the cluster if,

$$\left| Y_{current} - \breve{Y} \right| \leq \alpha \times H_{current}$$

and

$$\left| H_{current} - \breve{H} \right| \leq \alpha \times H_{current}$$

where $\breve{H}$ is the height of the blob and α is some parameter (See Figure 8).

The cluster with the maximum number of blobs is considered to be the identified number plate. Then we consider the blobs in the cluster, one at a time. The system as explained in [28] will identify the characters inside the blobs.

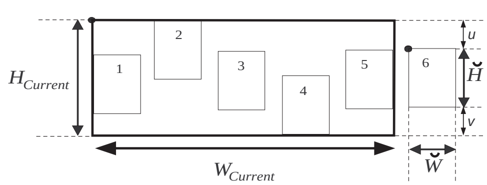


Fig. 8: The blob on the right is added to the cluster on the left, only if $u + v \leq \alpha \times H_{current}$.

IV. Experimental Evaluations

The proposed thresholding method was tested within the LPR system presented in [28]–[30]. This system uses geometric features [28], [30] and either a back-propagation multilayer perceptron (MLP-BP) or a support vector machine (SVM) to classify the characters. In this paper we use only the version with MLP-BP as it gave better results than SVM. This system uses Opencv library support to implement the thresholding method at its back end. While at its front end a fixed threshold (equal to 130) interface also provided to binarise the captured image [29]. In this paper we supplement the front end of the system with automatic selection of the threshold using

1) the local entropy method [21];
2) Otsu's method [4],
3) Multi level method [27],
4) the proposed method,

and compare the results obtained with those of the original system. CAIRO and CAIT members collected a dataset consist of 1216 images and it was used in the experiments.

The experiments were performed using the dataset on Intel Dual Core PC with 1.33Ghz processor speed. If all clusters identified in an image consist of a single blob, then we say that no number plate was identified in this image. The first row of Table II shows the percentage of images in which the number plate was not identified. Note that at this stage we do not consider cases where a number plate region had been found but it was totally wrongly placed. These cases will be identified only at the character recognition stage.

Of the clusters that are considered as candidate number plates, we consider first whether the number of blobs corresponds correctly to the true number of characters in the number plate. If it does, we consider that the segmentation was right. Table II also lists the percentage of images for which one, two, or more characters were not segmented, as well as the cases when more blobs than characters in the number plate were identified. Finally, we report the results of the recognition stage. Of the correctly segmented blobs, Table III gives the percentage of wrongly recognised characters for each of the tested methods. The same results are presented also in Figure 9.

Finally, the overall performance of the LPR system is reported in Table V, for the various thresholding methods, for license plate.

TABLE II: Segmentation results.

	Thresholding method				
	Local Entropy	**Otsu**	**Fixed**	**Multilevel**	**Proposed**
Not found	4.48%	41.17%	4.33%	4.05%	0.33%
Miss 1	2.36%	4.39%	3.10%	4.13%	1.40%
Miss 2	4.56%	3.58%	4.49%	5.45%	1.07%
Miss >2	7.33%	10.33%	7.19%	14.42%	0.99%
Extra	2.77%	1.46%	2.61%	5.14%	1.23%

TABLE III: Classification results with MLP-BP.

	Thresholding method				
	Local Entropy	**Otsu**	**Fixed**	**Multilevel**	**Proposed**
Wrong 1	5.46%	3.74%	5.39%	5.61%	1.48%
Wrong 2	1.22%	0.49%	1.14%	1.64%	1.97%
Wrong >2	0.65%	1.87%	0.65%	0.86%	1.40%

The 1216 images in the dataset includes 7835 characters in the number plates. Various schemes tested shows the percentage of correctly segmented characters and the percentage of the correctly recognized characters from those segmented are given in the first and second rows of Table IV.

However, the recognition of full number plates was one of the criteria judged for the performance of an LPR system. A number plate is recognised if all its characters are fully segmented and all are correctly recognised. The percentages

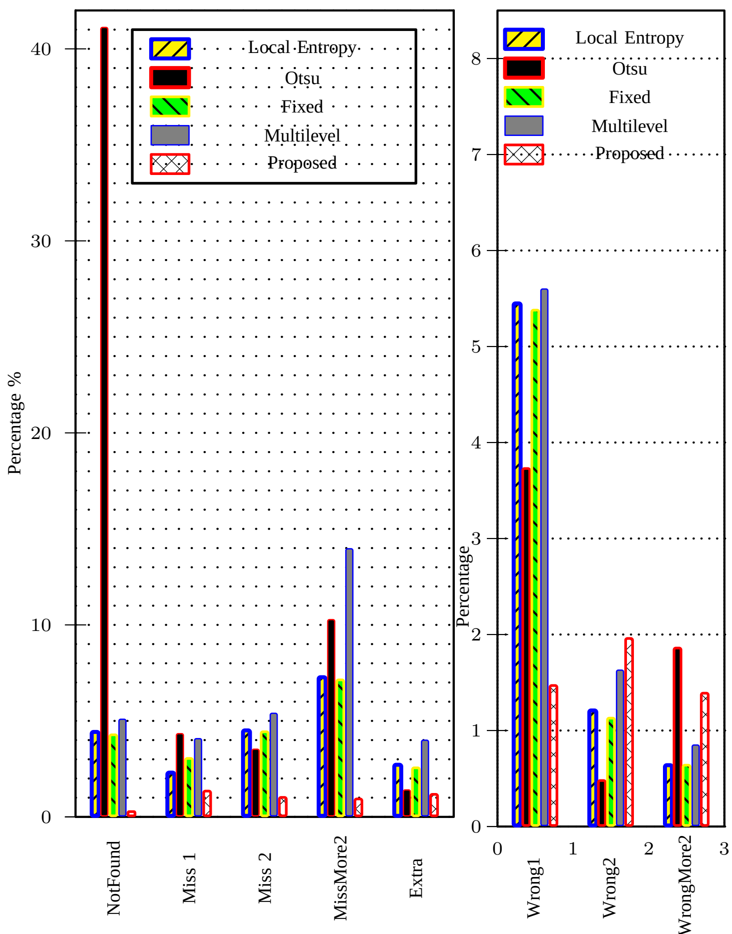


Fig. 9: Error Analysis for Local Entropy, Otsu, Fixed, Multilevel and the proposed framework in the (a)segmentation, and (b)classification phases.

TABLE IV: Blob error analysis for Local Entropy, Otsu, Fixed, Multilevel and the proposed framework based on correctly segmented and correctly recognised characters.

	Thresholding method				
	Local Entropy	**Otsu**	**Fixed**	**Multilevel**	**Proposed**
correctly segmented	58.49%	39.06%	78.27%	87.08%	92.33%
correctly recognised	97.11%	83.33%	90.81%	76.26%	97.61%

of correctly identified number plates (LPD) includes all images for which a number plate region was identified and at least 60% with the true number plate region was overlapped. The percentage of the correctly segmented characters (LPS) includes all images for which the number of blobs identified inside the candidate number plate region is at least equal to the number of characters in the number plate. Finally, the percentage of correctly identified number plates (LPR) includes only those images for which the full car number was recognised. These results are presented in Table V and in Figure 10.

Table V and Figure 10 are constructed based on three types of accuracy rate: LPD, LPS and LPR. The LPD, LPS and LPR

TABLE V: LPD, LPS and LPR rate for Local Entropy, Otsu, Fixed, Multilevel and the proposed framework.

	Accuracy rates				
	Local Entropy	**Otsu**	**Fixed**	**Multilevel**	**Proposed**
LPD	95.50%	58.83%	95.67%	94.86%	99.67%
LPS	78.41%	39.06%	78.27%	67.21%	94.98%
LPR	71.05%	32.55%	71.08%	59.11%	90.13%

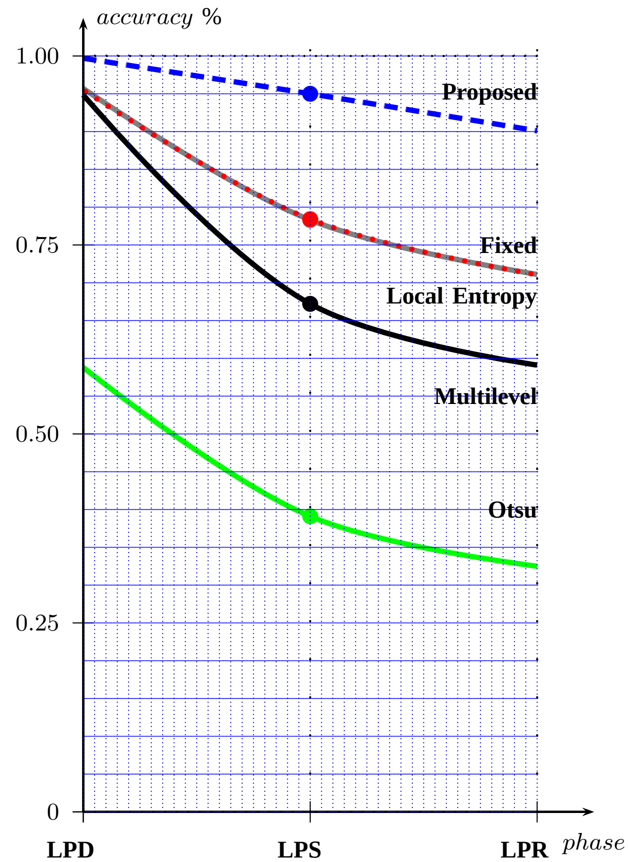


Fig. 10: LPD, LPS and LPR accuracy rates for Local Entropy, Otsu, Fixed, Local Entropy, Multilevel thresholds and the proposed framework.

accuracy rates are calculated as follows [31]:

$$LPD \quad rate \quad = \quad \frac{(1216-\mathrm{Notfound}-\mathrm{Smalloverlap})}{1216}, \qquad (12a)$$

$$LPS \quad rate \quad = \quad \left(\frac{(1216-\mathrm{Miss1}-\mathrm{Miss2}-\mathrm{Miss}{>}2)}{1216}\right) - LPD, \qquad (12b)$$

$$LPR \quad rate \quad = \quad \frac{(1216-Wrong1-Wrong2-Wrong\ 2)}{1216} - LPS. \qquad (12c)$$

Even though the fixed threshold [29] system has poor performance, it has the lowest recognition time (973.485ms) compared with the Otsu [4](3549.31ms), Local Entropy [21](2630.81ms), Multilevel [27] (3789.18ms) and the proposed threshold (4026.14ms). This is due to its lower complexity.

Some results of success and failures of the Otsu threshold [4] LPR system are shown in Figure 11. Some results of success and failures of the fixed threshold [29] LPR system are shown in Figure 12. Some results of success and failures of the multilevel threshold [27] LPR system are shown in Figure 13. Examples of successful and failed experiments of the system using the proposed thresholding method are shown in Figure 14.

V. Conclusions

Specific applications have their own peculiarities. License plate recognition systems are commercially available nowadays. However, generic LPR systems are not appropriate for all countries, due to variations in the lay out and the font of the characters used in the number plates. A Malaysian LPR system developed recently uses a fixed threshold to segment the number plate and the characters. In this paper, we showed that with the help of a taylor-made thresholding method we can increase the performance of the algorithm significantly. However, the proposed approach is computationally intensive and it cannot be used in its present form for a real time application. It may, however, be used for off-line processing of images with license plates. Another advantage of the proposed approach, is that the adaptive threshold values can adapt to the environment where the system is to be used, for example when there is a high or low contrast situation, such as during the night, mid-day, underground and in a rainy day.

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References

[1] S. Yoshimori, Y. Mitsukura, M. Fukumi, and N. Akamatsu., "A design of the object detection system using real-coded genetic algorithm," in *Proceedings of Joint conference on neural networks*, vol. 2, 20-24 July. 2003, pp. 1227–1231.

[2] K.-B. Kim, S.-W. Jang, and C.-K. Kim, *Recognition of Car License Plate by Using Dynamical Thresholding Method and Enhanced Neural Networks*. Lecture Notes in Computer Science, 2003, vol. 2756/2003, ch. Book Computer Analysis of Images and Patterns, pp. 309–319.

[3] B. R. Lee, K. Park, H. Kang, H. Kim, and C. Kim, "Adaptive local binarization method for recognition of vehicle license plates," *Lecture notes in Computer Science:Combinatorial Image Analysis*, vol. 3322/2004, pp. 646–655, 2004.

[4] N. Otsu, "A threshold selection method from gray level histograms," *IEEE Trans. Systems, Man and Cybernetics*, vol. 9, pp. 62–66, Mar. 1979, minimize inter class variance.

[5] H. Y. Chai, H. H. Woon, L. K. Meng, and Y. S. Li, "Non-standard malaysian car license plate recognition," in *Computer Applications and Industrial Electronics (ISCAIE), 2014 IEEE Symposium on*, April 2014, pp. 152–157.

[6] F. M. Khaleel, S. N. H. S. Abdullah, and M. K. B. Ismail, "License plate detection based on speeded up robust features and bag of words model," in *Smart Instrumentation, Measurement and Applications (ICSIMA), 2013 IEEE International Conference on*, Nov 2013, pp. 1–5.

[7] N. A. Bakar, M. R. M. Nawawi, A. R. Abdullah, A. Noordin, Z. Musa, and O. C. Xian, "Malaysian vehicle license plate recognition using double edge detection," in *Control System, Computing and Engineering (ICCSCE), 2012 IEEE International Conference on*, Nov 2012, pp. 422–426.

[8] K. Thanin, S. Mashohor, and W. Al-Faqheri, "An improved malaysian automatic license plate recognition (m-alpr) system using hybrid fuzzy in c++ environment," in *Innovative Technologies in Intelligent Systems and Industrial Applications, 2009. CITISIA 2009*, July 2009, pp. 51–55.

[9] M. D. Saleh, H. Mellah, A. Mueen, and N. D. Salih, "An efficient method for vehicle license plate xtraction," in *2008 International Symposium on Information Technology*, vol. 2, Aug 2008, pp. 1–5.

[10] C. M. Wang, J. D. Hong, G. C. Lin, J. Y. Su, and Z. F. Lin, "License plate location system using smart-phone with g-sensor," in *Intelligent Information Hiding and Multimedia Signal Processing (IIH-MSP), 2014 Tenth International Conference on*, Aug 2014, pp. 451–454.

[11] Y. Bolotova, A. Druki, and V. Spitsyn, "License plate recognition with hierarchical temporal memory model," in *Strategic Technology (IFOST), 2014 9th International Forum on*, Oct 2014, pp. 136–139.

[12] Z. Zhi-Yong and S. Yang, "The license plate image binarization based on otsu algorithm and matlab realize," in *Industrial Control and Electronics Engineering (ICICEE), 2012 International Conference on*, Aug 2012, pp. 1657–1659.

[13] B. Su, S. Lu, and C. L. Tan, "Robust document image binarization technique for degraded document images," *Image Processing, IEEE Transactions on*, vol. 22, no. 4, pp. 1408–1417, April 2013.

[14] Y. Yoon, K.-D. Ban, H. Yoon, and J. Kim, "Blob extraction based character segmentation method for automatic license plate recognition system," in *Systems, Man, and Cybernetics (SMC), 2011 IEEE International Conference on*, Oct 2011, pp. 2192–2196.

[15] J. He, Q. Do, A. Downton, and J. Kim, "A comparison of binarization methods for historical archive documents," in *Document Analysis and Recognition, 2005. Proceedings. Eighth International Conference on*, Aug 2005, pp. 538–542 Vol. 1.

[16] J. Fang, Y. Yuan, W. Ji, P. Tang, and Y. Zhao, "Licence plate images deblurring with binarization threshold," in *Imaging Systems and Techniques (IST), 2015 IEEE International Conference on*, Sept 2015, pp. 1–6.

[17] I. El Khatib, Y. Sweidan, S.-M. Omar, and A. Al Ghouwayel, "An efficient algorithm for automatic recognition of the lebanese car license plate," in *Technological Advances in Electrical, Electronics and Computer Engineering (TAEECE), 2015 Third International Conference on*, April 2015, pp. 185–189.

[18] S. Nigussie and Y. Assabie, "Automatic recognition of ethiopian license plates," in *AFRICON, 2015*, Sept 2015, pp. 1–5.

[19] F. Bouchara and T. Lelore, "A fast and robust super-resolved binarization algorithm for license plate recognition," in *Transparent Optical Networks (ICTON), 2012 14th International Conference on*, July 2012, pp. 1–5.

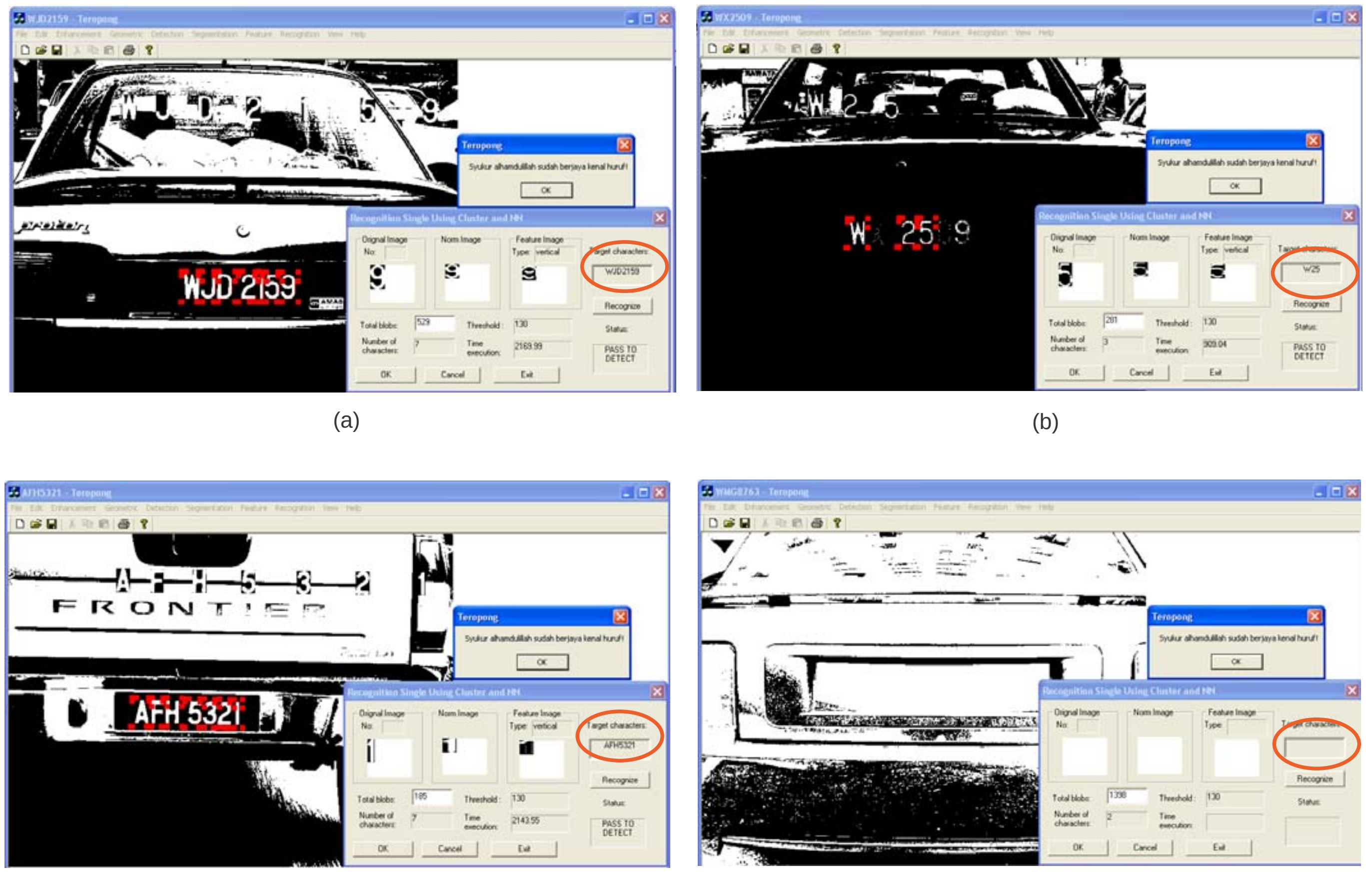
[20] J. Park, "An intelligent framework of illumination effects elimination for car license plate character segmentation," in *Machine Learning and Cybernetics (ICMLC), 2010 International Conference on*, vol. 3, July 2010, pp. 1268–1272.

[21] E. Y. Du and C.-I. Chang, "An unsupervised approach to colour video thresholding," in *IEEE Proc. International Conference on Multimedia and Expo ICME03*, vol. 3, no. III, 2003, pp. 337–40.

[22] M. L. Alhouse and C.-I. Chang, "Image segmentation by local entropy methods," in *Proc. International Conference on Image Processing*, vol. 3, 1995, pp. 61–64.

[23] P. Yang and O. A. Basir, "Adaptive weighted median filter using local entropy for ultrasonic image denoising," in *Proc. of the 3rd International Symposium on Image and Signal Processing and Analysis*, 2003, pp. 799–803.

[24] M. Bourjandi, "Image segmentation using thresholding by local fuzzy entropy-based competitive fuzzy edge detection," in *Computer and Elec-*



(a) (b) (c) (d)

Fig. 11: Examples of screen shots of Otsu [4] threshold LPR system for successful and unsuccessful detection. (a) Successfully guessed as ‘WJD2519’, (b) unsuccessfully guessed as ‘W25’. (c) Successfully guessed as ‘AFH5321’, and (d) unsuccessful detecting the location of the license plate.

trical Engineering, 2009. ICCEE ’09. Second International Conference on, vol. 2, Dec. 2009, pp. 298–301.

[25] A. Bardera, I. Boada, M. Feixas, and M. Sbert, “Image segmentation using excess entropy,” *Journal of Signal Processing Systems*, vol. 54, pp. 2005–214, 2009. [Online]. Available: http://www.springerlink.com/content/xq26752861ln0351

[26] M.-H. Horng, “A multilevel image thresholding using the honey bee mating optimization,” *Applied Mathematics and Computation*, vol. 215, no. 9, pp. 3302 – 3310, 2010. [Online]. Available: http://www.sciencedirect.com/science/article/B6TY8-4XH0MJW-2/2/2b4a2d8ebafd5906c000b776a42d05df

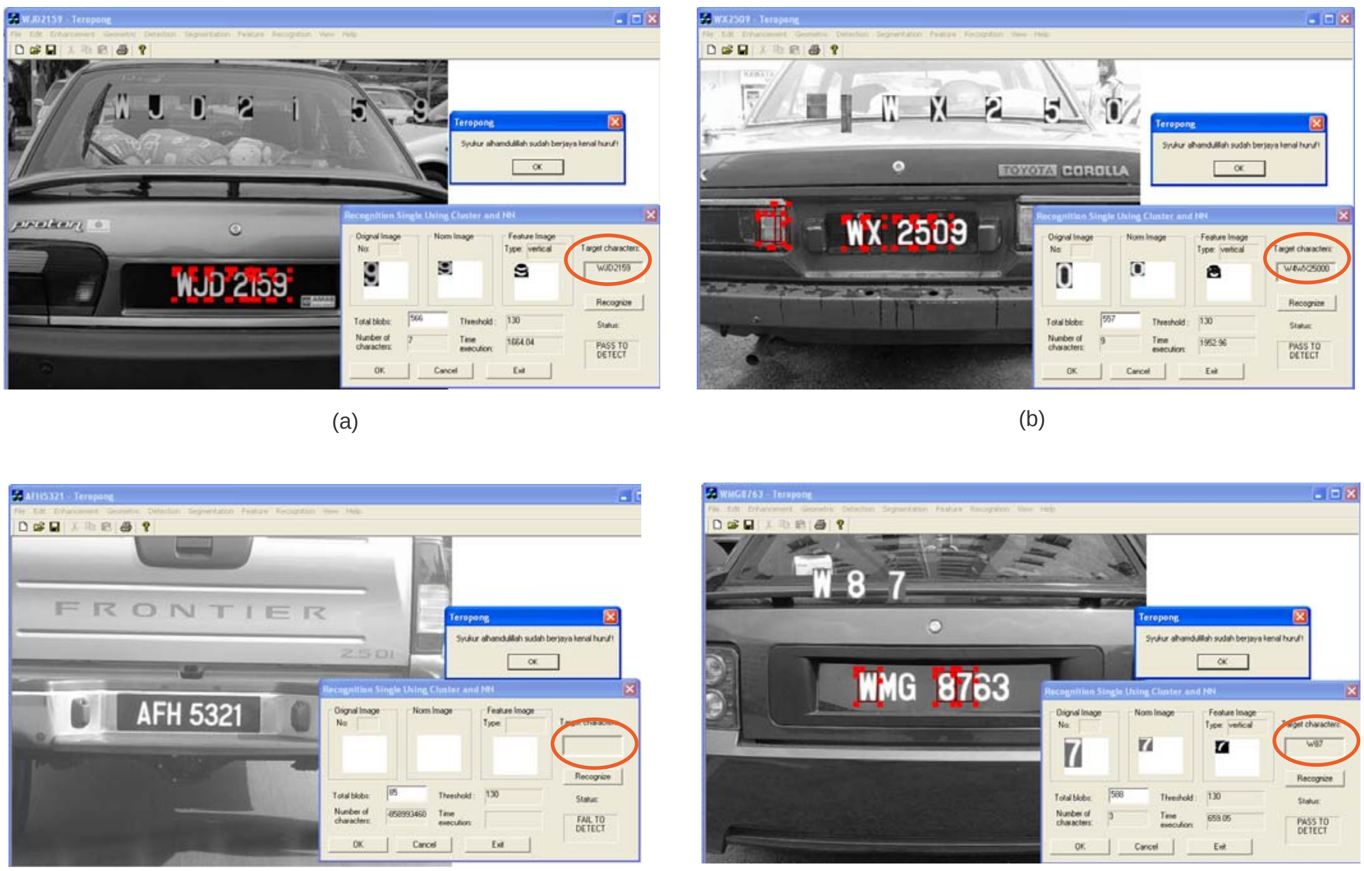
[27] S. Arora, J. Acharya, A. Verma, and P. K. Panigrahi, “Multilevel thresholding for image segmentation through a fast statistical recursive algorithm,” *Pattern Recogn. Lett.*, vol. 29, no. 2, pp. 119–125, 2008.

[28] S. N. H. S. Abdullah, M. Khalid, R. Yusof, and K. Omar, “License plate recognition based on geometry features topological analysis and support vector machine,” in *Proceedings of Malaysia-Japan International Symposium On Advanced Technology (MJISAT2007)*, Kuala Lumpur, Malaysia, 12th-15 November 2007, cD Proceeding.

[29] Y. K. Siah, T. Haur, M. Khalid, and T. Ahmad, “Vehicle licence plate recognition by fuzzy artmap neural network,” in *World Engineering Congress (WEC99)*, Sheraton Subang, Malaysia, 1999.

[30] S. N. H. S. Abdullah, M. Khalid, R. Yusof, and K. Omar, “Comparison of feature extractors in license plate recognition,” in *IEEE Proceedings of First Asia International Conference on Modelling & Simulation (AMS2007)*, Phuket, Thailand, 2007.

[31] J. Nijhuis, M. Brugge, and K. Helmholt, “License plate recognition using dtcnns.” in *Proceedings 1998 Fifth IEEE International Workshop on Publish Security Technology, 1997.*, 1998, pp. 212–217.



(a) (b) (c) (d)

Fig. 12: Examples of screen shots of Fixed [29] threshold LPR system for successful and unsuccessful detection. (a) Successfully guessed as ‘WJD2519’, (b) unsuccessfully guessed as ‘W4WX25000’, (c) unsuccessful to detect the location of the license plate, and (d) unsuccessful to detect the characters.

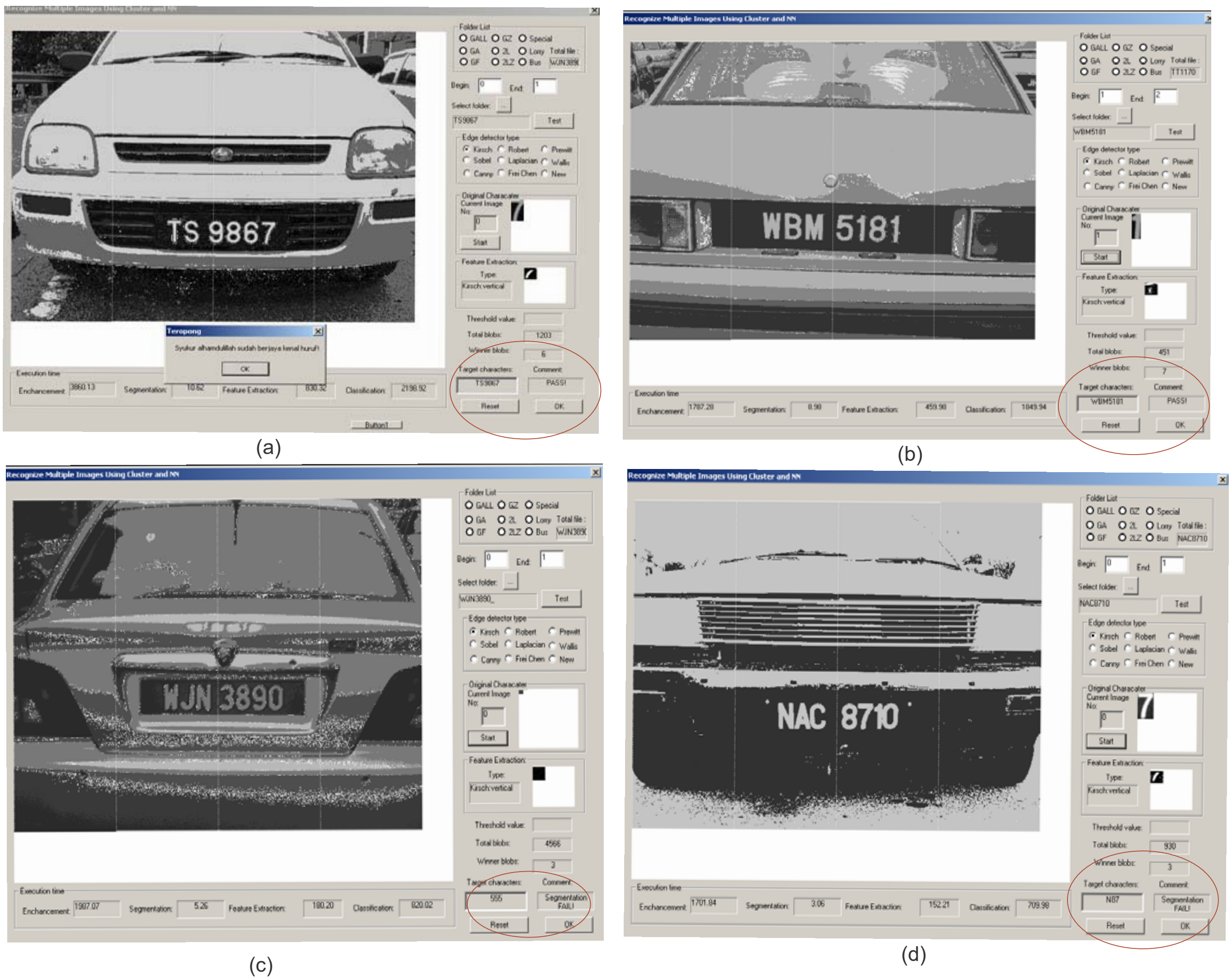
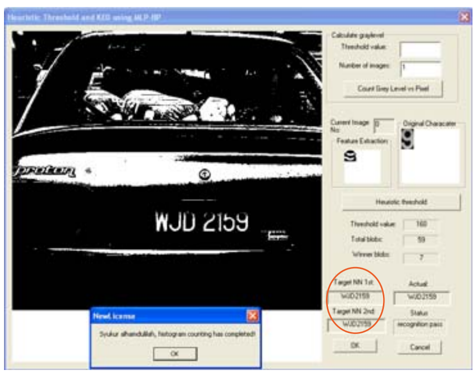
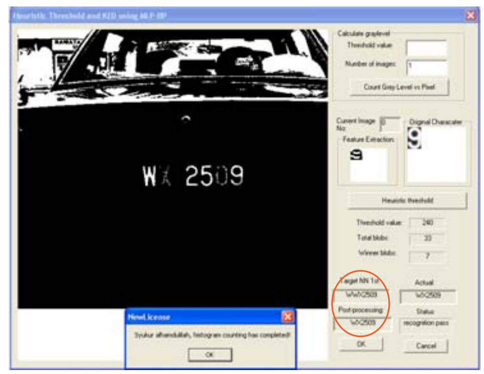


Fig. 13: Examples of screen shots of Multilevel [27] threshold LPR system for successful and unsuccessful detection. (a) Successfully guessed as ’TS9867’, (b) successfully guessed as ’WBM5181’. (c) unsuccessfully guessed as’555’, and (d) unsuccessful guessed as ’N87’.



(a)



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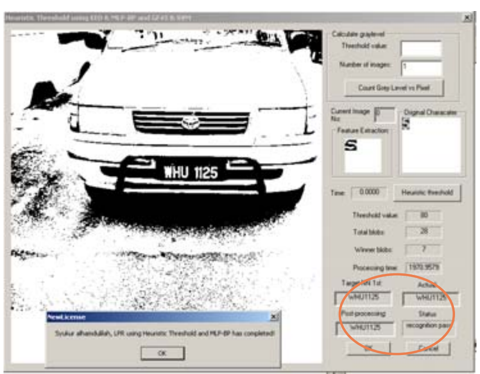
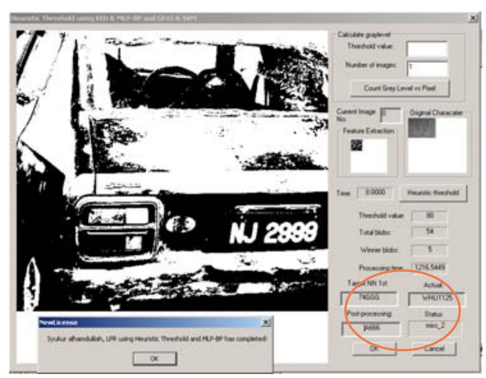


(c)



(d)

Fig. 14: Examples of screen shots of the output of the LPR system that uses the proposed thresholding method for (a) (b) successful, and (c) (d) fail detection.